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ИЗДАТЕЛЬСТВО «МАШИНОСТРОЕНИЕ» МОСКВА

MACHINE TOOL DESIGN

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На английском языке

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THE BASIC MACHINE TOOLS

CHAPTER 1

CLASSIFICATION, TYPE AND SIZE RANGES, AND IDENTIFICATION CODE OF MACHINE TOOLS. TOOL AND WORK MOTIONS IN MACHINE TOOLS

1-1. Machine Tool Classification

At the present time, the machine tool industry of the USSR produces a large number of metal-cutting machine tools, differing in purpose, processing capacities and size. We shall call the sum total of machine tool types and sizes being manufactured, as well as those planned for production in a certain definite period (for instance during a seven-year period) a type and size range. With the development of the Soviet machine tool industry and the higher requirements made to machine tools by the various branches of mechanical engineering, the type and size range is being continually extended.

The models of machine tools that are manufactured in lots in the USSR are designated by an identification code based on the classification worked out by the Experimental Research Institute for Metal-Cutting Machine Tools (ENIMS*). According to this classification, all machine tools are divided into nine main groups depending upon the type of processing operations they perform or the tools they employ (Table 1). Each main group, in turn, is further divided into nine subgroups (types) characterizing the specific purpose of the machine tool, its construction arrangement, degree of automaticity or the type of cutting tool employed.

The model designation consists of a combination of three or four numbers and letters. The first digit always indicates the number of the group according to the ENIMS classification; the second digit is the number of the subgroup. The last one or two digits represent one of the most important dimensions of the machine tool. In the different groups of machine tools, the last figures may stand for different, most characteristic, processing capacities of the machines. For example, model 1136 is a single-spindle automatic screw machine with a bar capacity of 36 mm, while model 2135 is an upright drill press with a drilling capacity of 35 mm.

The letter following the first digit indicates that the basic model of the machine tool has been modernized. Thus, the model 1A136 automatic is a modernized version of model 1136. The stepped-speed spindle drive in the earlier model has been replaced by a drive with infinitely variable speeds

*As this institute is known in the USSR from the abbreviation in Russian.

TAB

Machine tools	Group	Types of mac			
		1	2	3	4
Lathes	1	Automatics and semiautomatics single-spindle	multiple-spindle	Turret lathes	Cutting-off lathes
Drilling and boring machines	2	Upright drill presses	Semiautomatic single-spindle drilling machines	Semiautomatic multiple-spindle drilling machines	Jig borers
rinding and microfinishing machines	3	Cylindrical grinders	Internal grinders	Snagging grinders	Specialized grinders
ombination machine tools	4	General-purpose machines	Semiautomatic machines	Automatic machines	
ear- and thread-cutting machines	5	Shapers and planers for spur and helical gears	Bevel gear generators	Hobbers for spur and helical gears and splined shafts	Worm wheel and worm cutting machines
illing machines	6	Vertical knee-type milling machines	Continuous milling machines		Tracer-controlled milling and engraving machines
laners, shapers, slotters and broaching machines	7	Planers openside	double-housing	Shapers	Slotters

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hine tools				
5	6	7	8	9
Vertical turning and boring mills	Engine and facing lathes	Multiple-tool lathes	Specialized machine tools	
Radial drills	Boring machines	Precision boring machines	Horizontal drilling machines	
	Tool and cutter grinders	Surface grinders	Microfinishing machines	
				Miscellaneous machine tools of the various groups
Gear-tooth chamfering machines	Thread-milling machines	Gear finishing machines	Gear and thread grinders	
Vertical-spindle compound-table milling machines	Fixed-bed and planer type milling machines	Ram-head milling machines	Horizontal knee-type milling machines	
Horizontal broaching machines		Vertical broaching machines		

TABLE 1

Machine tools	Group	Types of ma			
		1	2	3	4
Cutting-off machines	8	Cutting-off lathes	Abrasive cutting machines	Circular-saw friction cutting machines	Straightening and cutting-off machines
Miscellaneous	9	Coupling and pipe threading and cutting machines	Saw-cutting machines	Centreless bar turning and straightening machines	

in the modernized model. Letters following the last number indicate a modification of the basic model. Thus, the basic model of the 1K62 engine lathe has the following modifications: model 1K62A with tracer controls; model 1K62Б which is the same lathe but of higher accuracy; model 1K62T which is a high-precision lathe; model 1K62ПУ with numerical controls; and model 1K62M wherein the speeds and feeds can be changed in the course of operation, which operates on an automatic cycle and whose design incorporates tracer controls and an automatic loading device.

To designate special and specialized machine tools (see below), each plant in the USSR engaged in their production has been allotted a symbol consisting of one or two letters. This is followed by the ordinal number of the given model. Thus, E3-9 is the designation of the specialized gear rack cutting machine manufactured by the Egoryevsk Gear-Cutting Machine Plant.

In respect to their degree of specialization, machine tools can be referred to one of the following groups:

(1) *General-purpose* (*universal*) *machine tools*, designed for performing a great variety of machining operations on a wide range of workpieces. They are employed chiefly in piece and small-lot production and for repair jobs (especially versatile machine tools are frequently called *omniversal*).

(2) *Single-purpose machine tools* are designed for performing a single definite machining operation. They may be readily set up for machining different-sized parts of the same type. Machine tools in this group include

(continued)

chine tools				
5	6	7	8	9
Bandsaw cutting-off machines	Circular cold sawing machines	Power hacksawing machines		Miscellaneous machine tools of the various groups
Tool testing machines	Dividing machines	Balancing machines		

those for machining the crankpins of crankshafts, for turning the cam contours on camshafts, etc.

(3) *Specialized machine tools* can be adapted to machine a certain definite workpiece by making the necessary changes in their construction. This group includes unit-built machine tools.

(4) *Special machine tools* are designed and manufactured individually and are intended for performing a certain definite operation in machining a certain definite workpiece. Specialized and special machine tools find application in large-lot and mass production.

Insofar as their weight is concerned, machine tools can be classified as *light-weight* (up to 1 ton), *medium-weight* (up to 10 tons) and *heavy-weight* (over 10 tons). The last-named are further divided into the subgroups: *large-size* (from 10 to 30 tons), *heavy* (30 to 100 tons) and *extra-heavy* or *unique* (over 100 tons).

ENIMS has divided all machine tools into five *accuracy classes*. Class H refers to machine tools of *standard* accuracy and includes the majority of the general-purpose models. Machine tools of *above-standard* accuracy, class II, are manufactured to the same drawings as the standard accuracy models, except that higher requirements are made to the accuracy with which the critical parts are manufactured, as well as to the quality of assembly and adjustments. Class B, *high* accuracy, machine tools have certain units that have been specially designed with the aim of maintaining the high accuracy standards. In addition, narrow tolerances are stipulated

for all the parts, as well as for their assembly and adjustments as a whole. In the manufacture of *precision* machine tools, class A, the accuracy requirements are even higher than for class B. *High-precision* or *master* machine tools, comprising class C, are intended for making the parts which determine the accuracy of machine tools belonging to classes A and B. Machine tools of the A, B, and C classes are to be installed in special constant-temperature rooms, in which constant temperature and humidity are maintained automatically, to ensure the required accuracy of operation.

1-2. Working and Auxiliary Motions in Machine Tools

In order to obtain a finished machine part of the required shape and size, surplus stock must be removed in the form of chips from the blank as it is machined in one or more metal-cutting machine tools.

The shape of the machined surface that is obtained depends upon the motions imparted by the machine to the work and cutting tool, upon the co-ordination of these motions and upon the shape of the tool. Surfaces of various shapes can be obtained on the same machine tool by varying the parameters of each motion (speed, co-ordination with other motions, direction, path, etc.) and by changing the tool.

The process of chip removal is effected by the *working motions* of the machine tool (formative motions) which are transmitted either to the cutting tool, or to the work, or to both simultaneously.

Working motions of a machine tool include the *primary cutting motion* and the *feed motion* (or motions); each of the working motions is specified by its speed or rate.

The primary cutting motion provides for cutting the chip from the blank at the *cutting speed* v equal to the velocity with which the chip leaves the work. The maximum permissible and practicable cutting speed depends upon the work material, tool material, machining method and other factors. It is determined experimentally.

The rate of feed, or speed of the feed motion, is substantially less than the cutting speed. The feed motion enables the cutting process to be extended to the whole surface to be machined on the work. Other conditions being equal, the rate of feed determines the cross-sectional area of the chip.

In addition to the working motions, the design of a machine tool always provides for *auxiliary motions* whose aim is to prepare the machine, work and tool for carrying out the cutting process, and to provide for the consecutive machining of several surfaces on one workpiece or similar surfaces on several workpieces. These motions include those providing for the handling and clamping of the blank in the machine, advance of the cutting tool

to the corresponding surface of the work and its withdrawal, the engagement and disengagement of the working motions, changing their speeds and direction, etc.

As a rule, the working motions of machine tools are power driven. The only exceptions are certain small machines which have hand feeds.

Auxiliary motions may be either hand or power operated. In automatic machine tools, practically all the auxiliary or handling motions are automated and are performed in a definite sequence by the machine itself at the required moments of the automatic operating cycle.

1-3. Primary Cutting Motions in Machine Tools

The most commonly used types of primary cutting motions are rotation and straight-line reciprocation.

The primary cutting motion of certain machine tools may be of a more complex nature but it can also be described as a combination of rotary and reciprocal motions.

Rotary motion may be transmitted either to the work, as in the lathe group of machine tools (Fig. 1*a*), or to the tool, as in the milling (Fig. 1*c*), drilling (Fig. 1*d*), grinding (Fig. 1*b*) and other machines, or to both simultaneously, as in drilling small-diameter holes. The cutting speed of a rotary cutting motion is

$$v = \frac{\pi dn}{1{,}000} \text{ m per min} \tag{1}$$

where d = diameter of the surface being machined on the rotating workpiece, or of the rotating tool, mm

n = rotational speed of the workpiece or tool, rpm.

Since the cutting speed in machine tools of the grinding group is determined in metres per second,

$$v = \frac{\pi dn}{1{,}000 \times 60} \text{ m per sec} \tag{2}$$

where d and n are the diameter and speed of the grinding wheel in mm and rpm, respectively.

A straight-line reciprocating primary cutting motion is employed in planers, shapers, slotters, broaching machines, power hacksaws, etc. This motion can be transmitted either to the tool, as in shapers (Fig. 2*b*), slotters (Fig. 2*a*) and certain other machines, or to the work, as in planers (Fig. 2*c*).

Cutting takes place periodically in most machine tools with a reciprocating primary cutting motion. The cutting cycle consists of a working stroke during which the tool cuts a chip, and the idle or return stroke when

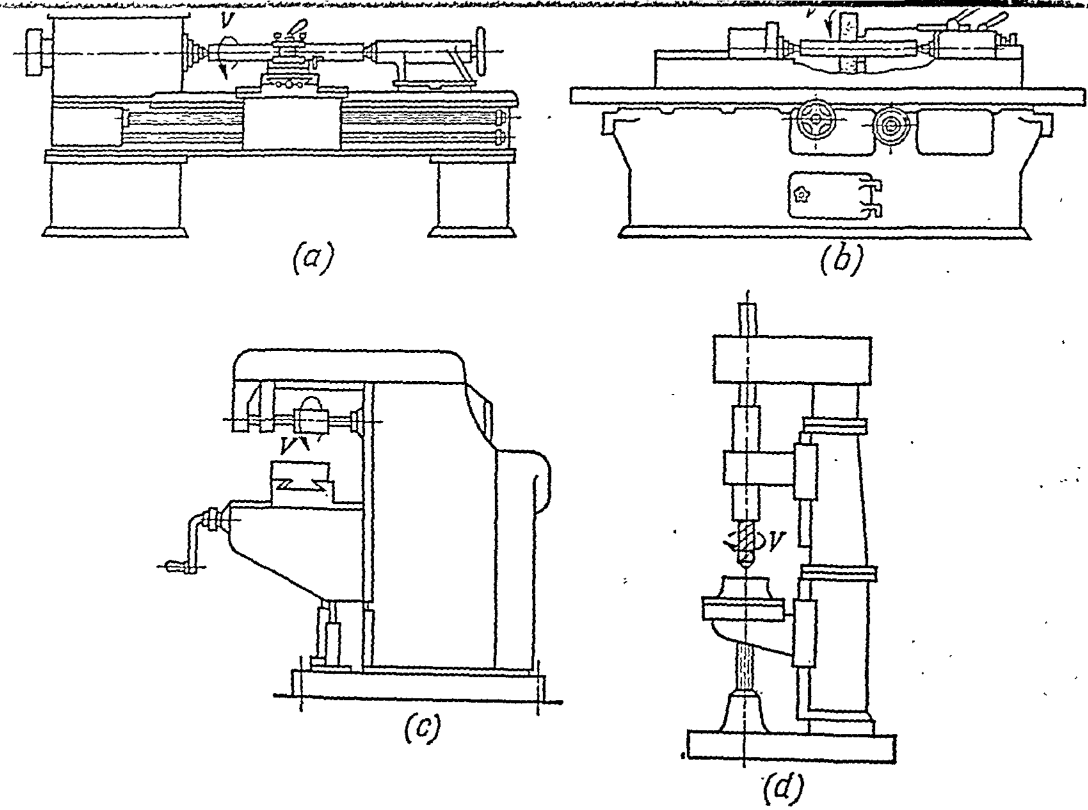


Fig. 1. Machine tools with a rotary primary cutting motion

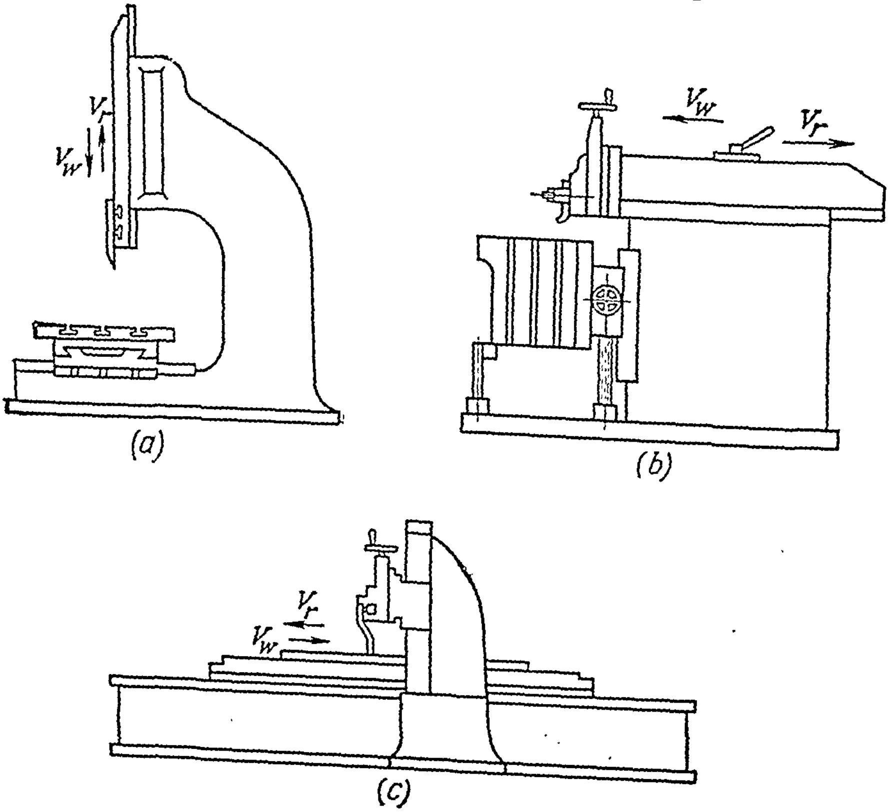


Fig. 2. Machine tools with a straight-line reciprocating primary cutting

the tool or work returns to its initial position. To reduce nonproductive time in machining (time losses) the speed of the return stroke is usually higher than that of the working stroke. The link-gear and crank-and-connecting-rod mechanisms, widely used in machine tools to convert rotational motion into reciprocation, do not provide for constant working and return speeds. This has led to the conception of the *average speed* of the working and return strokes and the maximum working and return speeds. The cutting speed v (or its average value) can be determined from the formula

$$v = \frac{L(K+1)n'}{1{,}000K} \text{ m per min} \tag{3}$$

where L = length of the working stroke, mm
n' = number of full strokes per min (one full stroke includes a working and a return stroke)
$K = \frac{T_w}{T_r}$, where T_w and T_r = times required for the working and return strokes, respectively.

Formulas (1), (2) and (3) can be used to determine the rotational speeds (rpm) or number of full strokes required for a machining operation if all the other values in the formulas are known. In many cases, special cutting speed charts are employed to determine the rotational speeds.

1-4. Gearing Diagrams of Machine Tools

The working motions are transmitted by some means to the operative units (spindle, slide, table, etc.) of the machine tool.

The source of motion in most modern machine tools is a three-phase induction motor Motion is transmitted to the operative units by means of kinematic chains consisting of separate links, each being a kinematic couple. Kinematic chains also serve to change the speeds and direction of motion of the operative units, to co-ordinate the motions of various units of the machine tool, to convert one type of motion into another, for example rotary into reciprocal motion (or vice versa), to summate motions, etc. In the general case, the kinematic chain of a machine tool consists of a number of transmissions—belt drives, toothed gearing, worm gearing, etc.—arranged in a definite sequence.

The conventional representation of the kinematic chains of a machine tool in a single plane (that of the drawing) is called its *kinematic* or *gearing diagram*. Graphical symbols for the diagrammatic representation of the principal elements of kinematic chains have been standardized by USSR Std GOST 3462-61 and are given in Table 2. In addition to the conventional representation of the transmissions or drives, a gearing diagram also indi-

TABLE 2

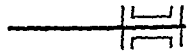
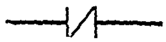
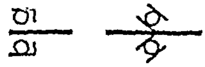
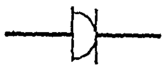
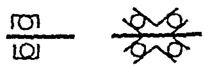
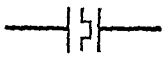
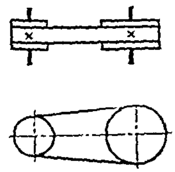
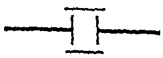
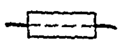
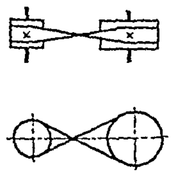
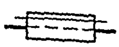
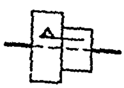
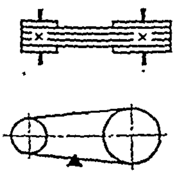
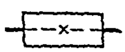
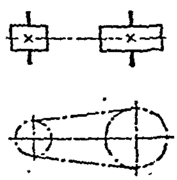
Description	Symbol	Description	Symbol
Shafts		Single-direction thrust	
Shafts couplings:			
Closed		Two-direction thrust	
Closed with over-load protection		Antifriction bear-ings: Radial	
Flexible		Single angular-contact	
Universal		Duplex angular-contact	
Telescopic		Belt drives:	
Floating		Open flat belts	
Toothed			
Parts mounted on shafts:			
Freely mounted		Crossed flat belts	
Sliding on feather			
Engaged with sliding key		V-belts	
Fixed			
Plain bearings:			
Radial		Chain drive	

TABLE 2 (continued)

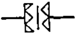
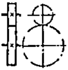
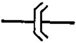
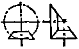
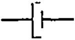
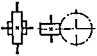
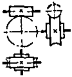
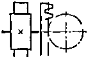
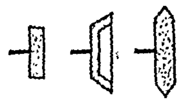
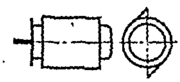
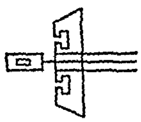
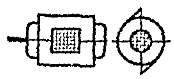
Description	Symbol	Description	Symbol
Toothed gearing:		Two-direction jaw clutches	
Spur or helical gears		Cone clutches	
Bevel gears		Single disk clutches	
Spiral (crossed helical) gears		Twin disk clutches	
Worm gearing		Single-direction overrunning clutches	
		Two-direction overrunning clutches	
Rack-and-pinion gearing		Brakes.	
		Cone	
Nut on power screw.			
Solid nuts		Shoe	
Split nuts		Band	
Clutches		Disk	
Single-direction jaw clutches			

TABLE 2 (continued)

Description	Symbol	Description	Symbol
Spindle noses:		Milling	
Centre type		Grinding	
Chuck type		Electric motors:	
Bar type		On feet	
Drilling		Flange-mounted	
Boring spindles with faceplates		Built-in	

cates the number of teeth of all gears and worm wheels and their modules, the number of starts of worms, pitches of lead screws, diameters of pulleys, and the power rating and speed of motors. In the gearing diagrams of machine tool service manuals, the transmissions can be numbered and all necessary data concerning them can be listed separately in a table.

In addition to mechanical drives, various hydraulic, pneumatic and electrical devices find application in modern machine tools, especially those of the semiautomatic and automatic types. Consequently, in addition to the gearing diagram, it is frequently necessary to construct hydraulic, pneumatic, electric circuit, or combined pneumatic-hydraulic and other diagrams.

1-5. The Transmission Ratio of a Drive

The principal kinematic parameter of a gear, worm, chain or belt drive is the transmission or gearing ratio, i.e., the ratio of the speed n_{dn}, rpm, of the driven shaft to the speed n_{dr}, rpm, of the driving shaft. Thus

$$i = \frac{n_{dn}}{n_{dr}}$$

It follows that for a belt drive

$$i=\frac{d_{dr}}{d_{dn}}$$

where d_{dr} and d_{dn} are the diameters of the driving and driven pulleys, respectively, while for toothed gearing

$$i=\frac{z_{dr}}{z_{dn}}$$

where z_{dr} and z_{dn} are the numbers of teeth on the driving and driven gears, respectively, and for worm gearing

$$i=\frac{k}{z}$$

where k = number of threads (starts) on the worm
z = number of teeth on the worm wheel.

If a number of drives are arranged consecutively, their total transmission ratio will be

$$i = i_1 \times i_2 \times i_3 \ldots$$

where i_1, i_2, i_3, ... are the transmission ratios of the separate drives.

Drives that convert rotary motion into rectilinear motion are characterized by the travel of the element moving in a straight line per revolution of the driving shaft. In the case of a power screw, this travel (of either the screw or nut) is equal to the lead of the screw:

$$H = kt$$

where t = pitch of the screw
k = number of threads (starts) on the screw.

The characteristic of a rack-and-pinion drive is the travel of the rack per revolution of the driving pinion. Thus

$$l = \pi mz$$

where z = number of teeth on the pinion
m = module of the gearing.

CHAPTER 2

METAL-CUTTING LATHES

Metal-cutting lathes constitute a considerable part of the metal-cutting equipment being used in industry. They comprise nine types of machine tools (see Table 1) differing in purpose, field of application, processing

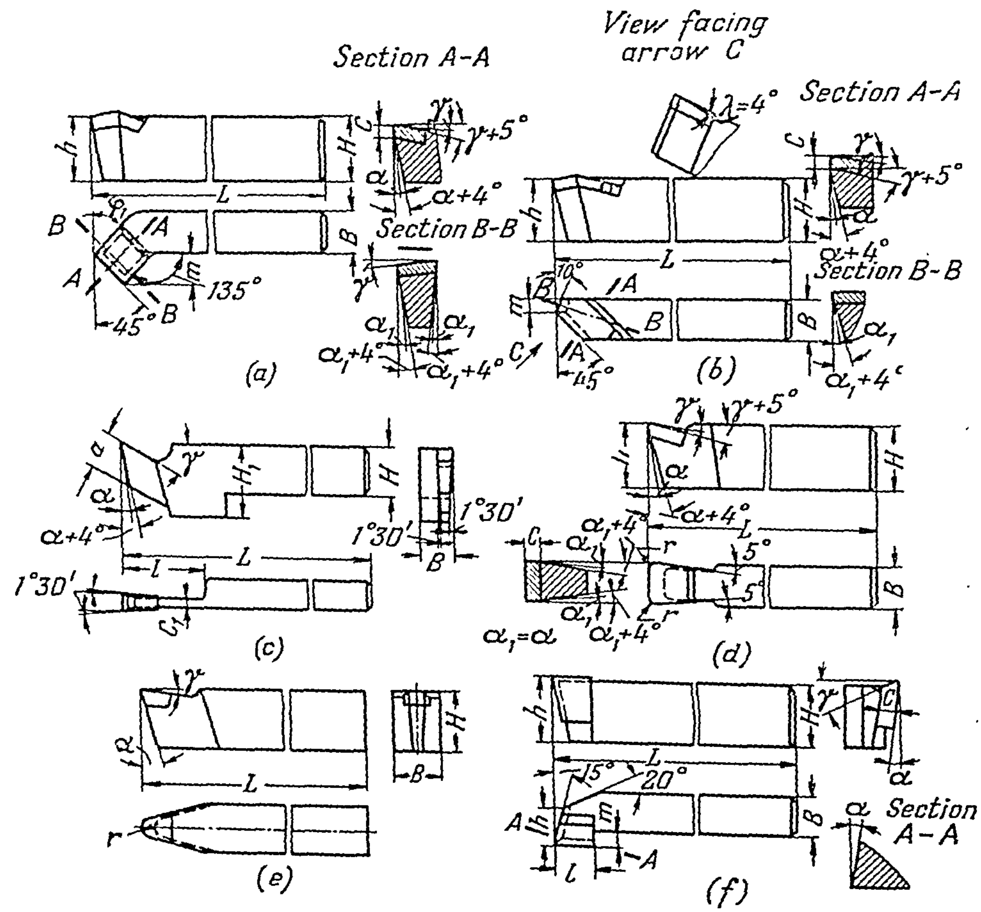


Fig. 3. Principal types of lathe tools:
(a) bent-shank right-cut straight-turning tool; (b) straight-shank right-cut straight-turning tool; (c) cut-off tool; (d) broad-nose finishing tool; (e) straight-turning finishing tool; (f) right-hand facing tool

capacities, construction arrangement, degree of automaticity and certain other features. The machine tools of each type may differ in size and construction.

The main purposes of the machine tools of the lathe group are to machine external, internal and face surfaces on solids of revolution, and also to cut threads.

Lathes employ single-point tools of various types (Fig. 3) for turning operations; drills, core drills and reamers for making holes; and taps and dies for cutting threads.

2-1. Engine Lathes

Engine lathes (Fig. 4) are the most versatile machines of the lathe group. They serve for machining workpieces bounded by surfaces of revolution and for cutting threads. Their chief application is in piece and small-lot production, and for repair work.

Table 3 indicates the grade of accuracy and class of surface finish (according to USSR standards) that are attainable in various machining operations performed on engine lathes.

TABLE 3

Machining operation	Grade of accuracy		Surface finish class, USSR St Std GOST 2789-59
	limits	mean economically feasible	
External turning:			
rough	4-7	5	3-4
finish	3a-4	4	5-7
high-accuracy	2a-3a	3	5-7
precision	1-2a	2	7-9
Boring			
rough	4-6	5	3-4
finish	3-4	4	6-7
precision	1-2	2	8-9
Drilling	4-7	5	3-5
Core drilling, counterboring, countersinking, spotfacing	4-7	5	3-6
Reaming:			
rough	2a-3a	3	5-7
finish (*precision*)	1-2a	2	7-9

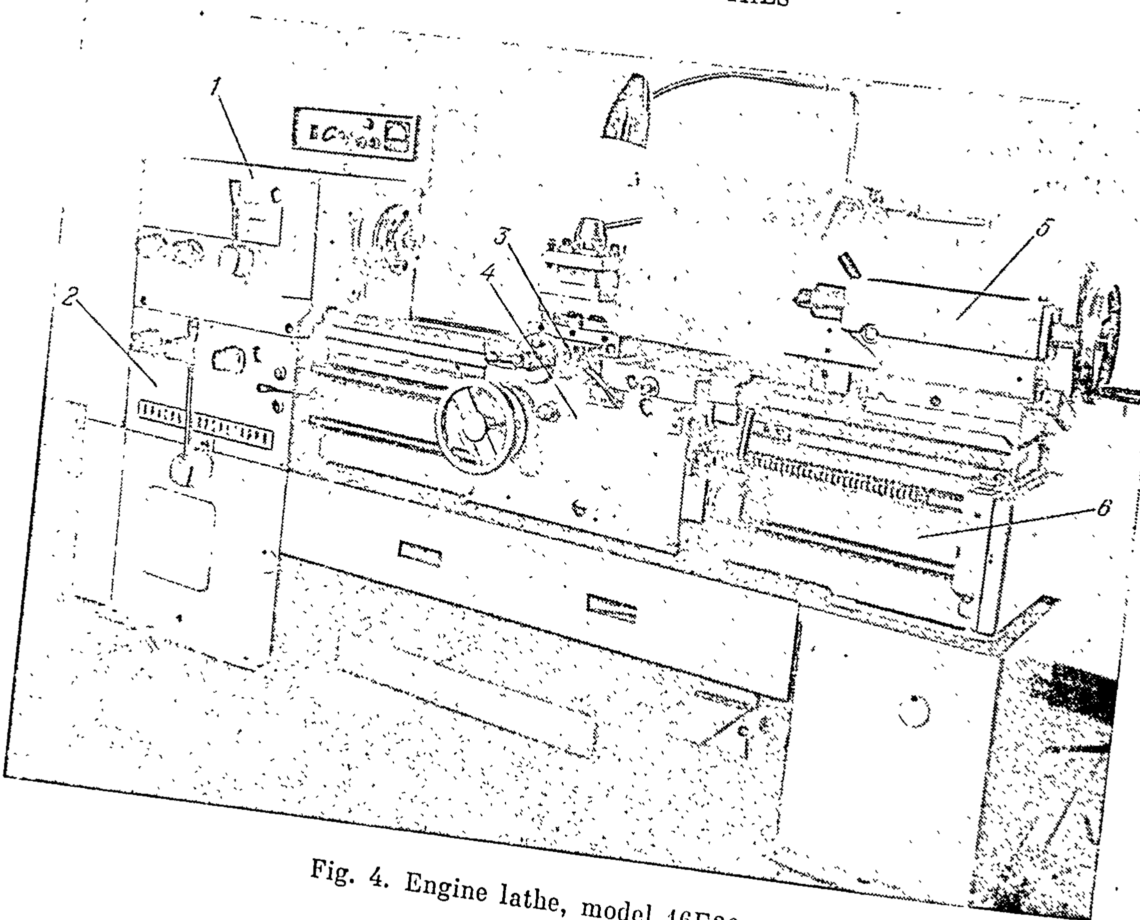


Fig. 4. Engine lathe, model 16Б20

-2. Construction Arrangement and Principal nits of Engine Lathes

All engine lathes have practically the same arrangement of the principal its. A typical example is the model 16Б20 engine lathe (Fig. 4) manufac-red in the Soviet Union. The principal units are: headstock *1* which may use the speed gearbox; quick-change feed gearbox *2*; carriage *3* with ron *4*; tailstock *5* and bed *6* to which the headstock and feed gearbox are ured.

n addition to these principal units, the model 16Б20 lathe also has lubri-ng and cooling systems and electrical equipment.

2-3. Dimensional Data for Engine Lathes

The main dimension of an engine lathe and indication of its capacity is the *maximum diameter D* (Fig. 5) *of work accommodated over the bed.** The clearance between the horizontal surface of the bed ways and the diameter D of the work should not exceed $0.04D$. Diameter D is approximately twice the height of centres.

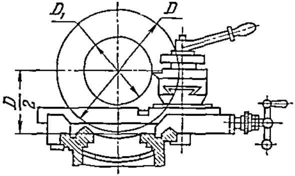


Fig. 5. Main dimensions of an engine lathe

USSR Std GOST 440-57 stipulates a series of engine lathe sizes in which D varies from 100 to 6,300 mm in a geometrical progression with a ratio of $\varphi = 1.26$ (the values being rounded off only slightly).

Another important dimension of a lathe is the *distance between centres*, as it determines the maximum length of workpiece that can be machined. It is measured with the tailstock shifted to its extreme right-hand position (but not overhanging the bed ways). Lathes with the same maximum workpiece diameter may have different distances between centres within the limits stipulated by the standard. For example, lathes with a maximum workpiece diameter of 400 mm are available with between-centres distances of 700, 1,000 and 1,400 mm. The maximum between-centres distance is not stipulated by the standard for the majority of heavy-duty lathes.

The third important dimension of a lathe is the *maximum diameter D_1 of workpiece accommodated over the carriage* (Fig. 5). On lathes made in the USSR it must not be less than stipulated in the standard mentioned above.

In addition to these chief dimensions, USSR Std GOST 440-57 also establishes the maximum spindle speed, bar capacity (maximum diameter

* This value is called the swing in the USA; one half of this value, i.e., the maximum radius of the work, is called the swing in Great Britain.

of bar stock passing through the hole in the spindle), size of the centre accommodated in the spindle (Morse or metric taper), maximum height of the tool, and maximum permissible net weight of the lathe (less that of the electrical equipment).

2-4. Type and Size Range of Engine Lathes

The machine tool industry of the USSR manufactures engine lathes in which the maximum diameter of workpiece accommodated ranges from 160 to 1,250 mm, and the maximum distance between centres is up to 12,500 mm.

The principal dimensional data of lot-produced Soviet engine lathes of standard accuracy are listed in Table 4.

Also available in the Soviet Union are lathes of above-standard (class П), high (class B) and precision (class A) accuracy and of special design, as well as lathes manufactured to the same drawings as certain standard-accuracy models but to higher accuracy. Small lathes, up to $D = 250$ mm, are produced in the П, B and A accuracy classes.

Using the general-purpose engine lathes as the basic models, lathes with various degrees of automaticity are also being manufactured. These include lathes equipped with tracer-controlled slides and operating to an automatic working cycle in machining work of the stepped shaft type, lathes with loading devices and with numerical controls. Certain models can be readily built into an automatic transfer machine and their design incorporates automatic speed changing during the course of operation.

2-5. Main Drives of Engine Lathes

The electric motor mounted on a machine tool, in conjunction with the whole train of transmissions from the motor to the spindle, is called the *main drive*. The construction of the main drive may vary in accordance with the purpose and size of the machine tool, but in any case it must:

(a) transmit the power and torque required for the cutting process;

(b) provide for engagement, disengagement and reversal of spindle rotation;

(c) ensure highly accurate and smooth rotation of the spindle at all the available speeds.

If stepped variation of spindle speeds is to be obtained, the main drive of the engine lathe may be designed as:

(a) a multiple-speed induction motor;

(b) a combination of a single- or multiple-speed induction motor with a stepped-type mechanical speed gearbox or, rarely, with cone pulleys.

TABLE 4

Model	Maximum workpiece diameter × distance between centres, mm	Speeds of main drive, rpm	Available power, kW	Net weight, kg approx.
16Б11	250 × 350 (710)	25 to 2,500	3.9/2.3	1,000 (1,150)
16Б16	320 × 500 (710; 1,000)	20 to 2,000	6.6/4.1	1,500 (1,600; 1,800)
16Б20	400 × 710 (1,000, 1,400)	16 to 1,600	6.6/4.1	2,100 (2,200; 2,400)
16Б25	500 × 1,000 (1,400; 2,000)	12 to 1,250	8.5/6.8	2,700 (3,000; 3,300)
16Б30	630 × 1,400 (2,800)	8 to 1,000	13	4,300 (5,500)
16Б40	800 × 2,000 (2,800; 4,000)	6.3 to 800	17	8,400 (9,000, 10,200)
16Б50	1000 × 2,800 (4,000, 5,000)	4 to 500	22	11,500 (13,800; 15,000)
16Б60	1,250 × 6,300 (maximum permissible weight of workpiece—12,500 kg)	2.5 to 315	30	23,000
1A665	1,600 × 8,000 (maximum permissible weight of workpiece—40,000 kg)	1.6 to 200	75	52,000
1A666	2,000 × 10,000 (maximum permissible weight of workpiece—40,000 kg)	1.28 to 160	75	63,000
1A667	2,500 × 12,500 (maximum permissible weight of workpiece—40,000 kg)	1.28 to 160	75	70,000
1A672	3,200 × 16,000 (maximum permissible weight of workpiece—63,000 kg)	0 96 to 120	100	120,000
1A685	4,000 × 20,000 (maximum permissible weight of workpiece—25,000 kg)	0.5 to 62	160	360,000
1A686	5,000 × 20,000 (maximum permissible weight of workpiece—25,000 kg)	0.5 to 62	160	400,000
1A687	6,300 × 20,000 (maximum permissible weight of workpiece—25,000 kg)	0.5 to 62	160	420,000

Infinitely variable spindle speeds can be obtained by employing:

(a) a variable-speed d-c motor;

(b) a mechanical speed-changing device or variable-speed drive (infinitely variable type);

(c) a combination of a variable-speed d-c motor or variable-speed drive with a stepped-type mechanical speed gearbox, or a variable-speed drive with a multiple-speed a-c induction motor.

2-6. Construction of the Main Drive in Engine Lathes

The great majority of up-to-date medium-size lathes have as their main drive a three-phase single- or, much less frequently, multiple-speed induction motor in conjunction with a stepped-type mechanical speed gearbox.

The model 1K62 lathe can serve as an example of a main drive in which the speed gearbox is housed in the headstock. The gearing diagram of this lathe is shown in Fig. 6 and a development through the speed gearbox shafts is shown in Fig. 7. The speed gearbox is driven through V-belts from a single-speed motor housed in the left leg of the bed. Shaft *I* carries twin friction clutch C_1 for engaging and disengaging forward and reverse rotation of the spindle. Shaft *II* is reversed due to the transmission of motion through the idler cluster gear (24*T* and 36*T*). By shifting the sliding cluster gears CG_1 and CG_2 along shafts *II* and *III*, six different forward speeds and three higher reverse speeds are transmitted to shaft *III*. Cluster gears CG_1 and CG_2 are controlled from a single handle *1* (Fig. 7) brought out on the front of the headstock.

Power can be transmitted from shaft *III* to the spindle along either of two gear trains:

(a) if the double cluster gear CG_3 is shifted to the left, power is transmitted directly to the spindle through the overdrive (65 : 43) so that the six higher speeds (from 630 to 2,000 rpm) are obtained;

(b) if the double cluster gear CG_3 is shifted to the right, power is transmitted to the spindle through the countergearing (cluster gear CG_4—shaft *IV*—cluster gear CG_5—shaft *V*), providing for four gear train combinations with gearing ratios of 1 : 1, 1 : 4, 1 : 4 and 1 : 16. It is evident that two of these combinations coincide. Thus, through the countergearing, the spindle obtains the three lower speed ranges (200 to 630, 50 to 160 and 12.5 to 40 rpm), each consisting of six speed steps. One speed (630 rpm) is obtained twice, once in direct engagement with the spindle and once with engagement through the countergearing. Therefore, only 23 different spindle speeds are available. Cluster gears CG_3, CG_4 and CG_5 are also controlled from a single lever *4* (Fig. 7). Mounted on shaft *III* is a brake whose appli-

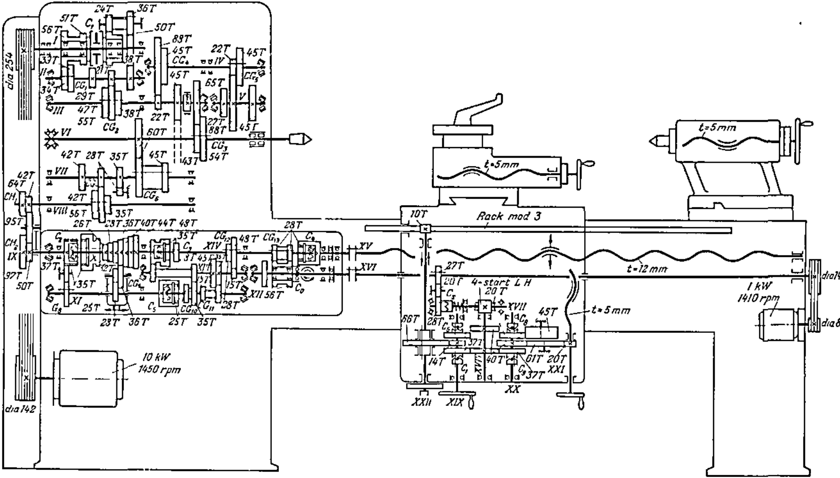


Fig 6. Gearing diagram of the model 1K62 engine lathe

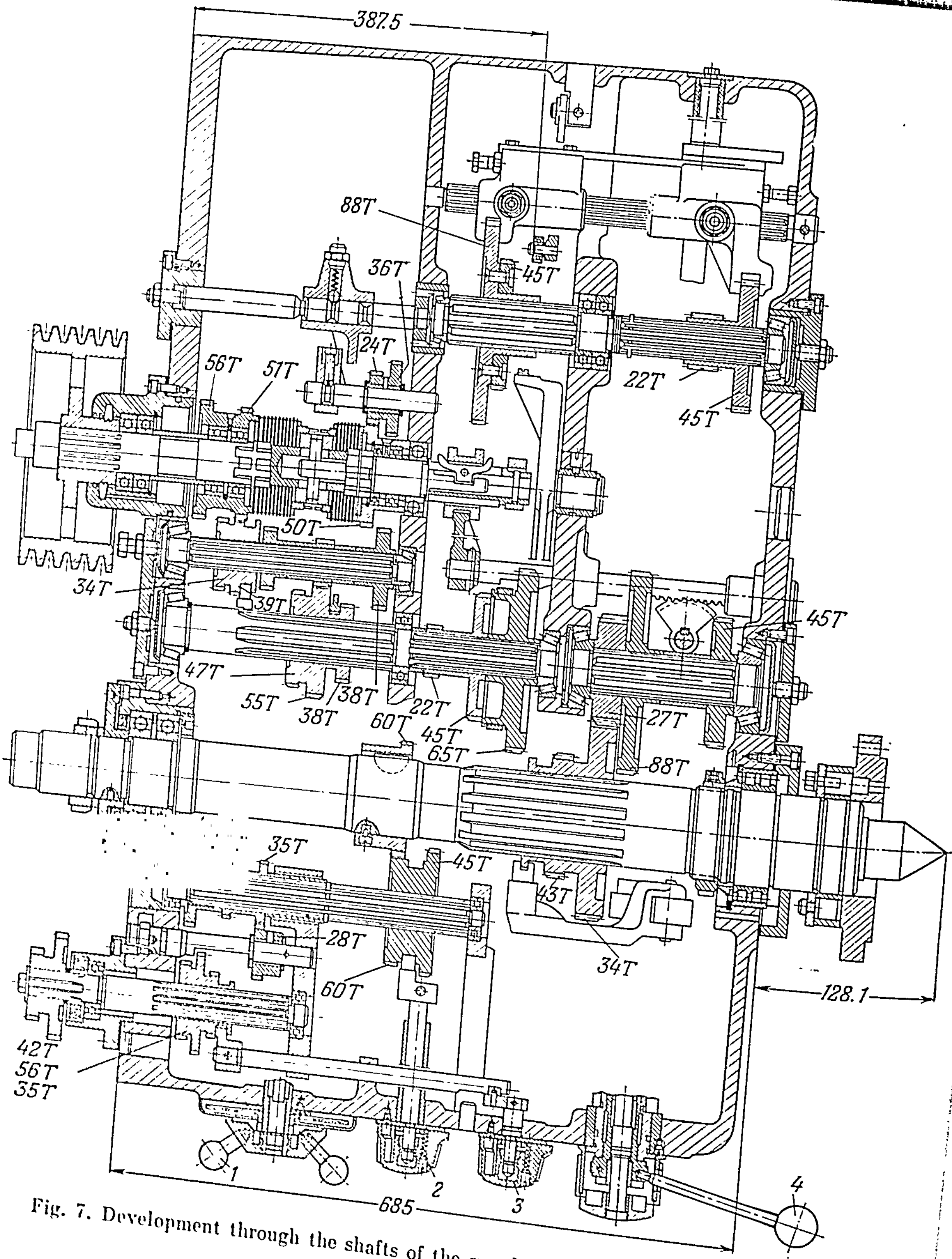


Fig. 7. Development through the shafts of the speed gearbox on the model 1K62 engine lathe

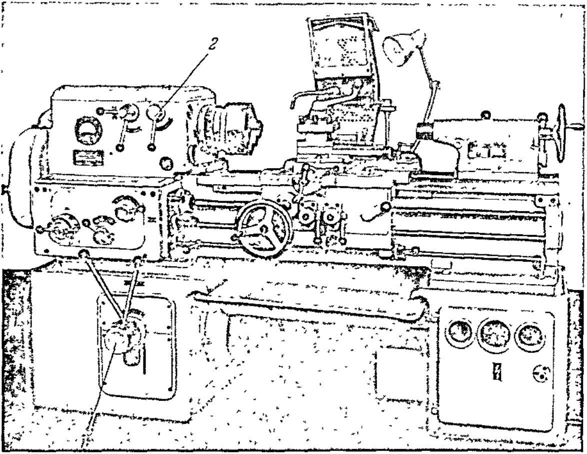


Fig. 8. Engine lathe, model 1A616

cation and release are interlocked with the mechanism for engaging clutch C_1.

In the model 1A616 lathe (Fig. 8), the speed gearbox is arranged in a separate housing which is located in the left leg of the bed. The output shaft of the gearbox is linked to the drive shaft of the headstock through V-belts. This is known as a separate drive. It provides smoother spindle rotation and is frequently found in precision machine tools

The speed gearbox is powered through V-belts from a separate motor mounted on a bracket at the rear of the left leg of the bed. The belt tension is adjusted by moving the motor along the plate on which it is mounted. Shifting four cluster gears CG_1, CG_2, CG_3 and CG_4 (Fig. 9) by means of two

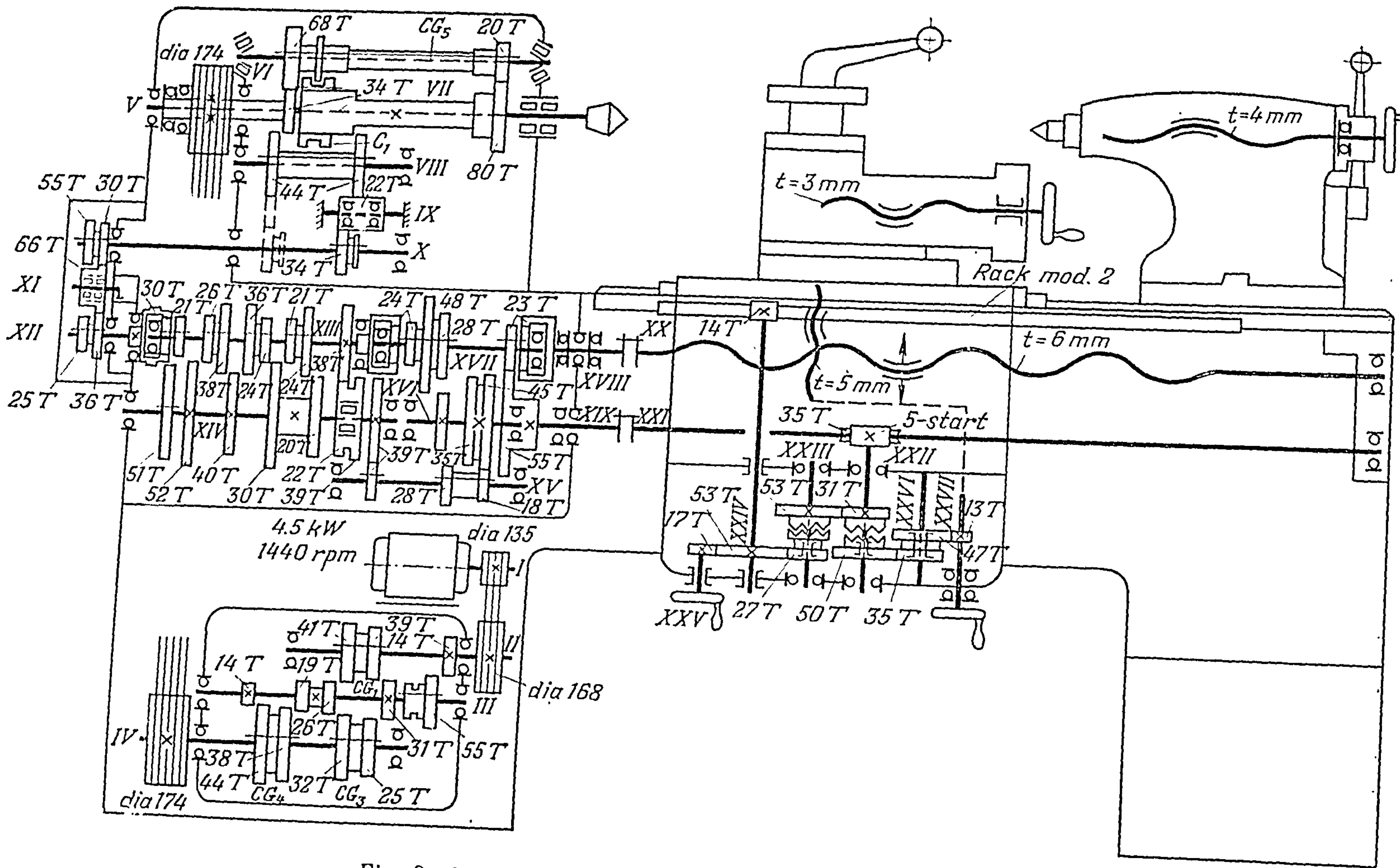


Fig. 9. Gearing diagram of the model 1A616 engine lathe

levers *1* (Fig. 8) into various combinations of engagement provides 12 different speeds on the output shaft *IV*. V-belts transmit rotation further to the headstock driving pulley which is mounted on antifriction bearings so as to relieve the driving shaft of bending stresses due to belt tension. The headstock contains countergearing with a ratio $i = 1 : 8$. The belts are tensioned by vertical adjustment of the speed gearbox.

Rotation may be transmitted to the spindle along either of two gear trains:

(a) short train—the spindle obtains 12 high speeds (90 to 2,240 rpm) directly from pulley shaft *V* when clutch C_1 is engaged and countergearing CG_5 is disengaged;

(b) long train—the spindle obtains 12 low speeds (11.2 to 280 rpm) through countergearing CG_5 when clutch C_1 is disengaged.

Three spindle speeds, obtained with the countergearing engaged, coincide with corresponding speeds obtained when the countergearing is disengaged. Consequently, only 21 different spindle speeds (instead of 24) are available. The engagement and disengagement of countergearing CG_5 and clutch C_1 are interlocked and are controlled from a single lever *2* (Fig. 8). No main friction clutch has been provided in this model and the spindle is started, reversed and braked by means of the drive motor.

Various frictional variable-speed drives have found application in medium- and small-size engine lathes to provide infinitely variable spindle speeds. The main drive of the model 1M620 engine lathe (Fig. 10) incorporates a frictional variable-speed drive, invented by Svetozarov and developed in TSNIITMASH*, which operates in conjunction with a stepped-type speed gearbox in the headstock**. A drive of this construction enables stepless spindle speeds to be obtained in a range from 12 to 3,000 rpm. The frictional speed-changing drive itself provides an infinitely variable speed range from 750 to 3,000 rpm on its output shaft. Various engagements of the sliding cluster gears CG_1, CG_2 and CG_3 enable the following four stepless spindle speed ranges to be obtained: 12 to 47, 47 to 190, 190 to 750 and 750 to 3,000 rpm. An auxiliary 1-kW motor is used to control the variable-speed drive. Spindle rotation is reversed with the aid of clutch C_1 and sliding gears SG_4 and SG_5.

In smaller lathes the infinitely variable drive may consist of a frictional speed-changing device alone, without the stepped-type speed gearbox.

Heavy-duty engine lathes are designed, as a rule, with infinitely variable spindle speeds as this enables their production capacity to be substantially increased. Mechanical speed-changing drives do not prove suitable for this

*Central Research Institute of the Heavy Engineering Industries (USSR)

**A wide-belt variable-speed drive with spreading sheaves was installed on certain lathes of this model.

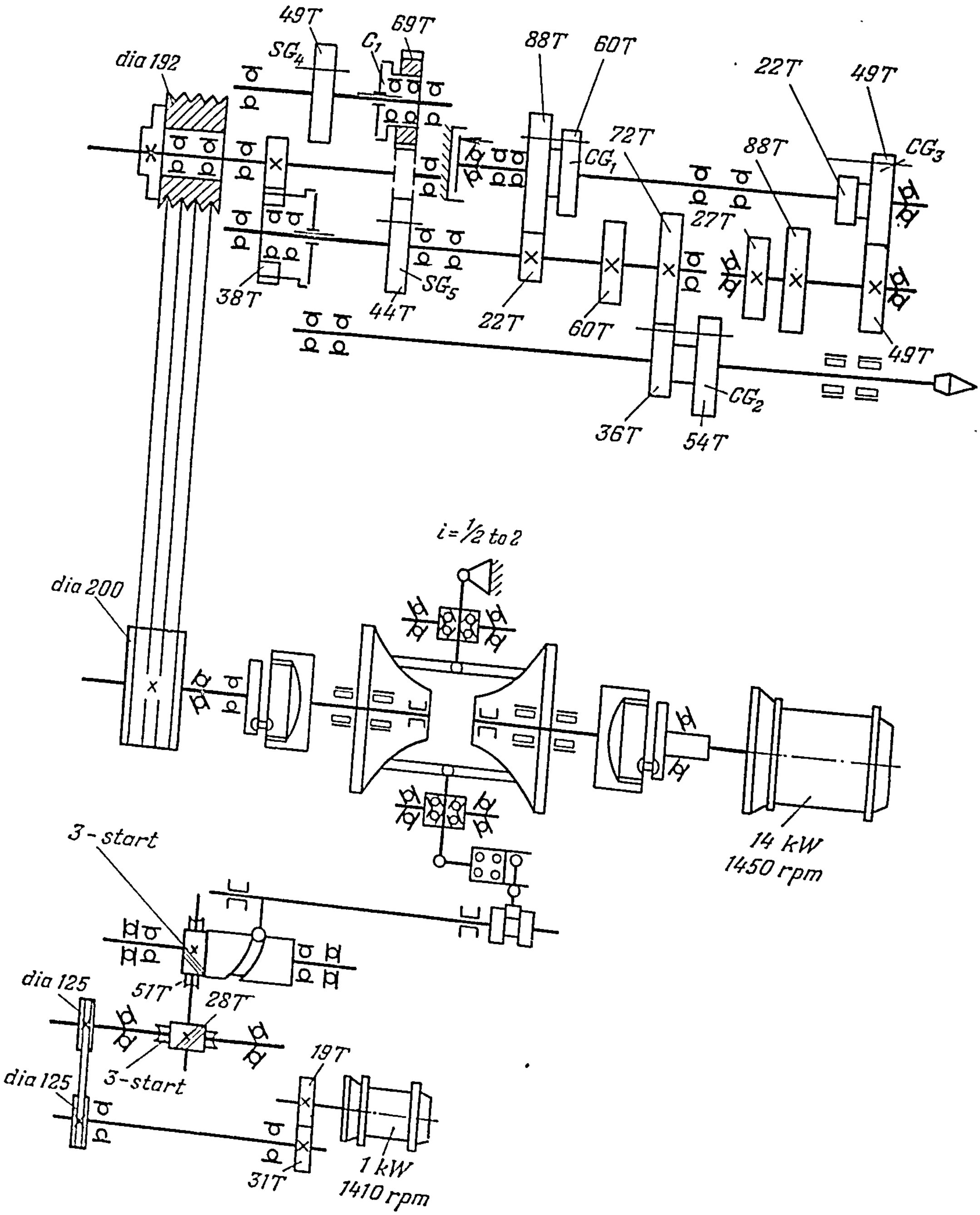


Fig. 10. Gearing diagram of the model 1M620 engine lathe

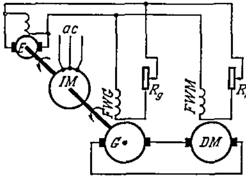


Fig. 11. A motor-generator-motor setup for obtaining stepless spindle speeds

purpose however, and electrical systems are resorted to to obtain stepless drive motor speeds. The latter are used in combination with a stepped-type mechanical speed gearbox.

The most extensively used electrical system for obtaining stepless speeds in heavy-duty lathes is the motor-generator-motor setup (*M-G-M*) which is also known as the Ward-Leonard, or adjustable-potential, system (Fig. 11). It comprises four electrical machines: a-c induction motor *IM* which drives d-c generator *G* and exciter *E* (low-power d-c generator), and the d-c drive motor *DM* of the lathe. The speed of motor *DM* is varied by changing the resistances R_g and R_m in the field windings *FWG* and *FWM* of the generator and drive motor, respectively, which are supplied with direct current from exciter *E*. The range of speed adjustment of such a system may be as high as 10- or even 15-fold. It should be noted that motor *IM* and generator *G* must have a power rating not less than that of the drive motor *DM*. Thus, the cost of an *M-G-M* system is 7 or 8 times that of a single a-c motor.

Table 4 lists the principal data concerning the main drives of Soviet engine lathes.

2-7. Feed Drives of Engine Lathes

The purpose of the feed gear train in an engine lathe is to provide power travel of the cutting tool, clamped on the carriage, relative to the rotating work in turning operations and in cutting threads.

The source of motion (initial link) of the feed gear train is the spindle, and for this reason the feed in engine lathes is measured and specified in millimetres per spindle revolution (mm per rev).

The feed mechanism should provide for: feed engagement and disengagement without stopping spindle rotation; reversal of the feed with the

spindle continuing to rotate in the previous direction; reversal of both the feed and direction of spindle rotation simultaneously; changing the rate of feed in a substantial range; and traversing the tool by hand in reference to the work.

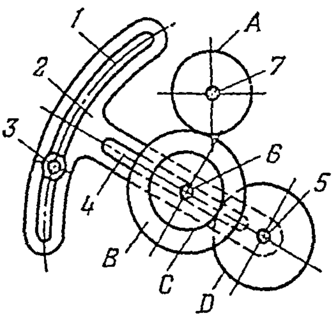


Fig. 12. Change-gear quadrant

In the model 1K62 lathe (see Fig. 6), the feed gear train (shaft *VII*) is driven either directly from the spindle (cluster gear CG_6 is shifted to the left) or through the countergearing of the main drive gear train (cluster gear CG_6 is shifted to the right and its gear $45T$ meshes with gear $45T$ on shaft *III*). In the latter case, depending upon the positions of the cluster gears CG_4 and CG_5 of the countergearing, shaft *III* may rotate at a speed 2, 8 or 32 times that of the spindle. The countergearing (cluster gears) CG_4 and CG_5 in the main drive gear train, and cluster gear CG_6 are used in this case in the feed gear train as a coarse feed unit (unit for multiplying the pitches of threads being cut or the rates of feed).

The triple sliding cluster gear CG_7 on shaft *VIII* is the *reversing unit* which forms two forward and one reversing drives in its three positions. This cluster gear is controlled from knob *3* (see Fig. 7).

In the various positions to which cluster gears CG_3, CG_4, CG_5, CG_6 and CG_7 can be shifted, shaft *VIII* may rotate at speeds equal to those of the spindle; at speeds 2-, 4-, 8-, 16- and 32-fold those of the spindle; or at speeds slower than those of the spindle by factors of 1.51, 2 or 3.02.

Rotation is transmitted to the quick-change feed gearbox through change gears CH_1 and CH_2 (see Fig. 6) of the quadrant. In the general case such a quadrant consists of four change gears *A*, *B*, *C* and *D* and the quadrant proper *2* (Fig. 12) with two slots, one slot (*4*) being radial and the other (*1*) circular.

Slot *1* permits quadrant *2* to be swivelled about axis *5* of the shaft and to be rigidly clamped by nut *3*. Stud *6*, on which the cluster gear *B* and *C* (or two separate change gears keyed on a single bushing) freely rotates, can be adjusted along the radial slot *4* and clamped in the required position with nut *8*. The swivel of the quadrant and the adjustment of the stud enable four change gears with various numbers of teeth to be put into mesh in two pairs. Change gears $CH_1 = 42T$ and $CH_2 = 50T$ are installed on the quadrant of the model 1K62 lathe to obtain longitudinal feeds and to cut metric and English threads. To cut module and diametral pitch worm threads, change gears $CH_1 = 64T$ and $CH_2 = 97T$ are used. In both cases, a single intermediate gear $95T$ is mounted on the stud of the quadrant.

The quick-change feed gearbox contains a number of toothed (gear) clutches, sliding gears and cluster gears, as well as the speed-changing device consisting of a gear cone rigidly mounted on shaft X and a tumbler cluster gear CG_9 which can be shifted axially along shaft XI and swung into mesh with one of the gears of the cone. In cutting threads the feed gearbox transmits rotation to the lead screw XV; in turning operations and in cutting scrolls rotation is transmitted to the feed rod XVI. The use of the feed rod to obtain feeds in turning operations enables the accuracy of the lead screw, required in cutting threads, to be retained over a longer period of service.

A series of consecutive feed rates or thread pitches is obtained when tumbler gear CG_9 is shifted from gear to gear of the gear cone, and these feeds and pitches are increased 2-, 4- and 8-fold by shifting cluster gears CG_{11} and CG_{12}. Tumbler gear CG_9 and cluster gears CG_{11} and CG_{12} are controlled from a single star wheel. The feed gear train is switched over to thread cutting of various types (metric, English, module worm and diametral pitch worm) or to feed from the feed rod by the corresponding engagements of clutches C_2, C_3, C_4 and C_5, sliding gear G_8 and cluster gear CG_{10} which are controlled from a handle.

The *carriage* (Fig. 13) is the final element of the feed gear train and serves to clamp the tool and to transmit to it the feed motion in reference to the rotating work. It is composed of four main parts: *saddle 1* which travels on the bed ways along the axis of the work; *cross slide 2* which travels along ways on the saddle in a direction square to the work axis; *swivel base 4* with ways along which *compound rest 3* travels. The saddle and cross slide can be fed both manually and by power. The swivel base *4* can be set at an angle to the line of centres of the lathe and clamped with bolts whose heads enter an annular T-slot in the cross slide; this feature is chiefly used in turning tapers (see Sec. 2-10). The compound rest is fed only by hand. The dials mounted on the feed screws have scales which enable tool travel distances to be read off with sufficient accuracy for all ordinary purposes.

As a rule, heavy-duty engine lathes have several carriages.

The *apron* (Fig. 14) converts rotary motion of the lead screw or feed rod into travel of the carriage along the bed ways together with the apron which is rigidly secured to the saddle. The rotation of the feed rod is also used to effect power traverse of the cross slide.

Power traverse through the lead screw (for thread cutting) is engaged by closing the half-nuts (Fig. 15). As the name implies, this is a split nut consisting of two halves *1* and *2* which can move along guides in the apron. By turning lever *4* on the front of the apron, the half-nuts can be either brought together or spread apart, thereby closing them over the lead screw or releasing it. The half-nuts are actuated by a disk *5* with shaped slots for pins *3* press-fitted into the half-nuts.

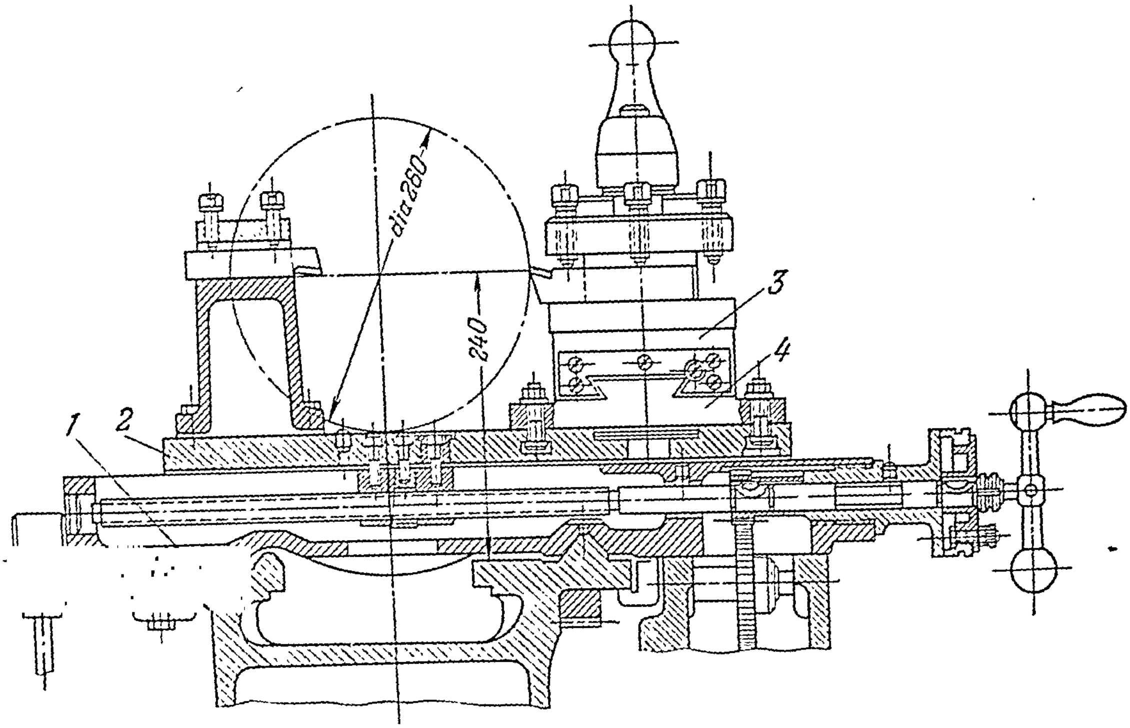


Fig. 13. Carriage of the model 1K62 engine lathe

Rotation is transmitted from the feed rod through gear $27T$ (see Fig. 6), sliding along the rod, to the worm gearing of the apron. Depending upon which of the claw clutches C_6, C_7, C_8 or C_9 is engaged, rotation is transmitted further from the worm wheel either to the rack pinion $10T$ to obtain the longitudinal feeds, or to the gear $20T$ mounted on the feed screw XXI of the cross slide to obtain power cross feeds. In the model 1K62 lathe all of these clutches are engaged by a single lever (Fig. 16) and the direction in which the lever is shifted coincides with the direction of tool feed. The carriage is traversed longitudinally by hand by turning the handwheel on shaft $XXII$ with the lever for engaging power feed in its neutral (middle) position. The apron contains a device which prevents simultaneous engagement through both the lead screw and feed rod since such a conflicting engagement would lead to breakage of the mechanism.

A safety jaw clutch C_s (see Fig. 6) is mounted on the worm shaft. It protects the feed gear train against overloads, and is also used in turning to a positive stop (see Sec. 2-12). The spring of this clutch is adjusted so that the clutch can transmit a definite torque. If the torque exceeds the permissible value the clutch begins to slip with a clicking noise.

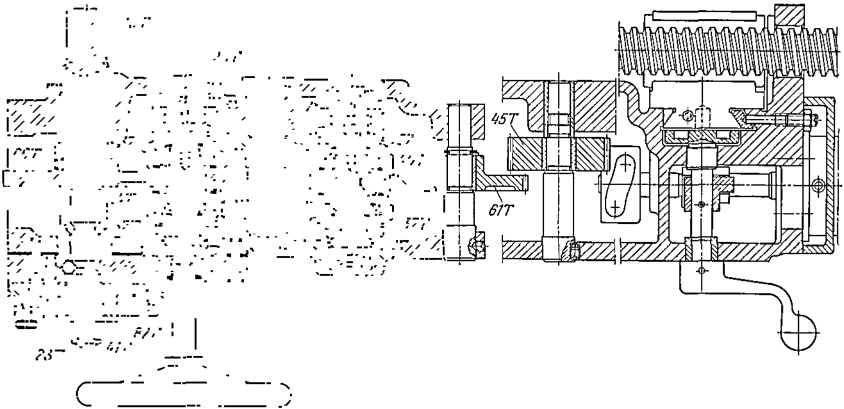


Fig. 14 Apron of an engine lathe

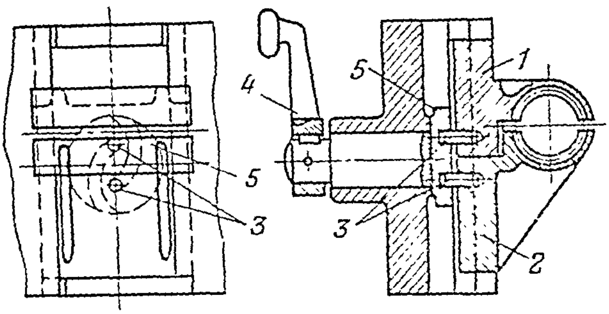


Fig. 15. Half-nuts

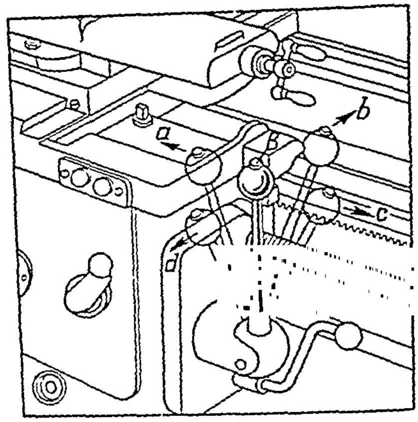


Fig. 16. Feed engagement lever of the model 1K62 engine lathe

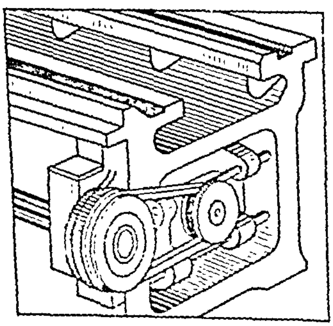


Fig. 17. Rapid traverse drive of the model 1K62 engine lathe

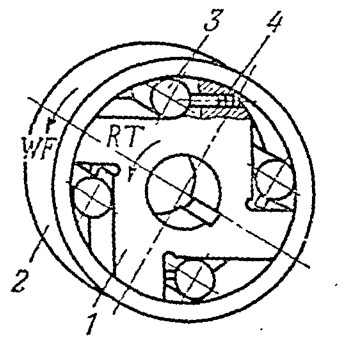


Fig. 18. Overrunning clutch

The reduction of the time required for handling motions is an important possibility of increasing the production capacity of machine tools. For this reason, most up-to-date machine tools are equipped with mechanisms for rapid idle traverse of the cutting tool. A separate 1-kW motor, mounted for this purpose on the right end of the bed in the model 1K62 lathe (Fig. 17), is linked to the feed rod through a V-belt drive. A single-direction overrunning clutch C_0 in the feed gearbox enables the feed rod to be driven either from the feed gearbox or from the rapid traverse motor.

The overrunning clutch (Fig. 18) consists of shell *2*, inner member *1*, rollers *3* and springs *4* which push the rollers into the jamming position. This type of overrunning clutch can transmit a torque when the rollers are jammed in one direction only.

In the feed gearbox the shell of the overrunning clutch is rigidly secured to the cluster gear 56*T* (see Fig. 6) and the inner member—to the feed rod *XVI*. When the rapid traverse motor is not switched on, rotation is transmitted to the feed rod from the feed gearbox. When this motor is switched on the inner member rotates in the same direction as the shell but at a higher speed, disengaging the clutch and permitting the feed rod to overrun its drive from the feed gearbox and providing for a rapid traverse motion of the tool. As soon as the motor is switched off the working feed gear train is automatically re-established. The rapid traverse motor is switched on by pressing the button *B* (see Fig. 16) in the ball end of the lever for engaging power feeds. The rapid traverse mechanism provides for rapid longitudinal traverse at a speed of 3.4 m per min and cross traverse at 1.7 m per min.

In heavy-duty engine lathes having several carriages, rapid longitudinal and cross traverse motions are powered by separate motors mounted on each carriage.

2-8. Tailstock

The main purpose of a tailstock on an engine lathe is to support long work during operation. It is also used to clamp tools for making holes (twist drills, core drills and reamers) and for cutting threads (taps and dies).

The principal parts of a tailstock (Fig 19) are: spindle *1*, body *2*, base *12* and strap clamp *11*. Tailstock spindle *1* can be moved in or out of the body by means of screw *4*, nut *5* and handwheel *8*; it can be clamped at any position by binding member *9* which is pulled up tight by lever *3*. With the aid of setting screw *10*, body *2* can be offset crosswise in reference to base *12* along its guide key The tailstock is clamped on the bed by the action of strap clamp *11* which is operated by strap *14*. The latter is actuated by lever *7*, eccentric shaft *6* and link *13*.

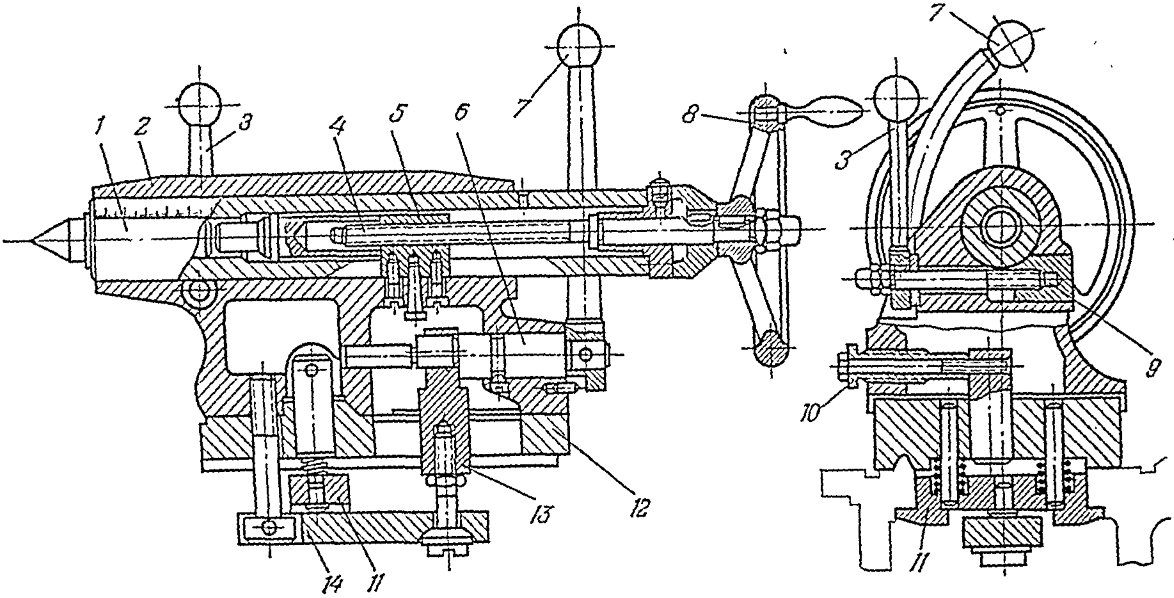


Fig. 19. Tailstock of an engine lathe

On heavy-duty engine lathes the tailstock is moved along the bed ways by power, the drive being from a separate motor. This considerably reduces the handling time required to adjust the tailstock, as well as operator's fatigue.

2-9. Holding the Work and the Tools in Engine Lathes

Depending upon the shape of the work and its length, it can be held in a chuck, between centres, on a faceplate or on a mandrel.

The most commonly employed method of holding work is to clamp it in a chuck alone (Fig. 20*a*) if it is short enough, or to support the free end with the dead (tailstock) centre (Fig. 20*b*) if its length is considerable in relation to its diameter. Chucks may be universal, or self-centring, usually of three-jaw design, in which the jaws move together towards the centre in clamping the work; or they may be independent (usually of four-jaw design) in which each jaw moves independently of the others. The latter type of chucks is especially useful in clamping irregular and nonsymmetrical workpieces.

Most of the universal three-jaw chucks are of the scroll type (Fig. 21*a*) in which a scroll *2* is cut on the rear face of bevel gear *4*. Projections or teeth in the form of a rack on the bottom of jaws *1* engage the threads of the scroll.

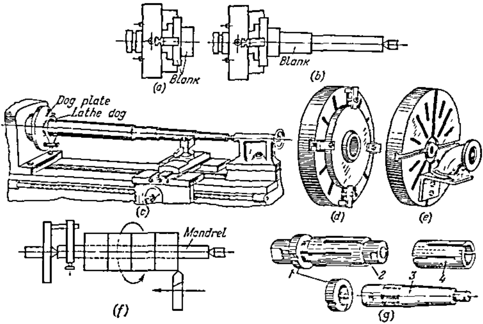


Fig 20. Methods of holding the work on an engine lathe

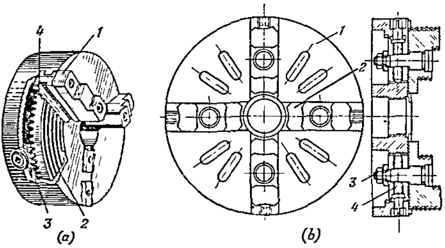


Fig. 21. Jaw chucks for lathes

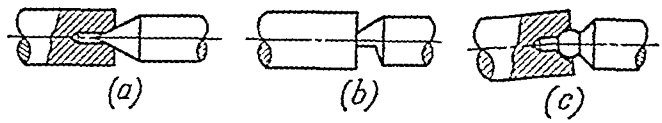


Fig. 22. Types of dead centres

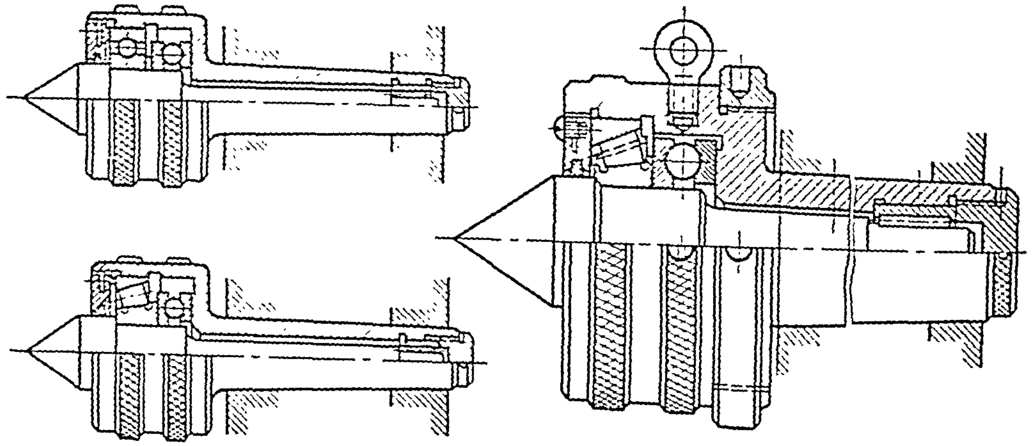


Fig. 23. Ball and roller bearing centres

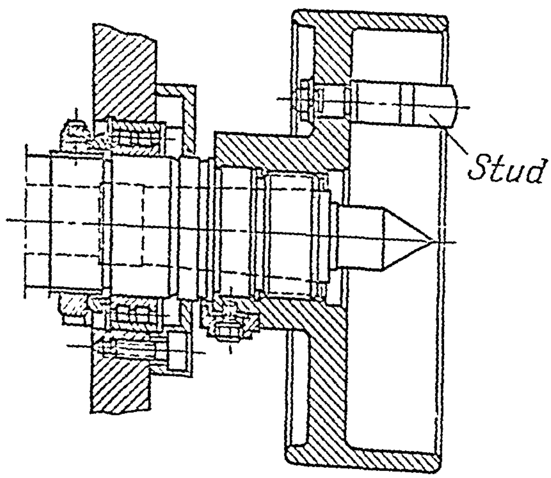


Fig. 24. Dog plate of the model 1K62 engine lathe

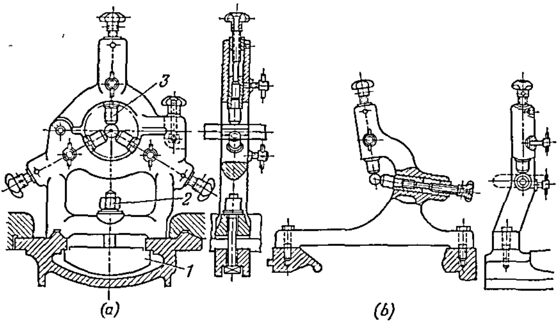


Fig. 25. Rests

The chuck jaws close simultaneously and clamp the work when bevel gear *4* is rotated by bevel pinion *3*. The latter has a square socket to accommodate the chuck wrench. An independent four-jaw chuck (Fig. 21*b*) consists of the body *1* with slots along which each of the four jaws *2* is moved by its own screw *4* independently of the other jaws. After clamping the work the jaws are locked to the chuck body by the clamping bolts *3*.

Spring collet chucks are used on small lathes in turning bar stock (see Part Six in Vol. IV).

Long work of the shaft type, having centre holes in its ends, can be mounted between centres (Fig. 20*c*) inserted into the taper holes of the headstock and tailstock spindles. The type of centre (Fig. 22) to be used depends upon the machining operation being done.

In ordinary straight-turning operations the type *a* centre is employed; if the end of the work is to be faced, a half-centre, type *b*, is used. A ball-ended centre, type *c*, proves the most efficient in turning long tapers (see Sec. 2-10). The points of centres can be hard faced with cemented carbide to increase their wear resistance. *Ball and roller bearing centres* (Fig. 23) can be efficiently used for high work speeds. The work is driven by the stud of a *dog plate* (Fig. 24) screwed onto the spindle nose and a lathe dog (Fig. 20*c*) clamped on the work with a screw.

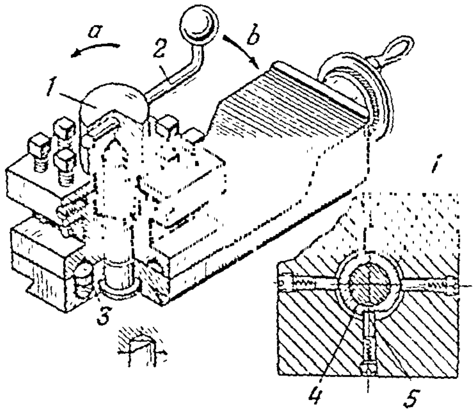


Fig. 26. Square turret

Rests (Fig. 25), supplementary intermediate supports, are used in turning long slender work to prevent it from being bent by the action of the cutting forces. A steady rest (Fig. 25*a*) is clamped in the required position on the bed by base clamp *1* and bolt *2*. Then the work is centred by means of adjustable jaws *3*. The jaws are locked by screws. A follower rest (Fig. 25*b*) is mounted on the lathe saddle and travels together with the carriage. It is usually set just after the cutting tool so that it supports the work where the cutting force is applied and prevents springing of the work.

Work having a hole as the locating datum can be machined on a *mandrel* (Fig. 20*f* and *g*) which is held in a chuck or mounted between centres. If the hole has been made to narrow tolerances a solid (slow-taper) mandrel (Fig. 20*f*) is used. Such mandrels are forced into the work with a hand press and the work is held by friction alone. If the hole diameter varies in a comparatively small range an expansion mandrel (Fig. 20*g*) is used. The outside diameter of this mandrel can be changed by shifting spring sleeve *4* with the aid of two nuts *1* and *2* along taper *3* of the mandrel proper. The spring sleeve has internal tapered and external cylindrical surfaces.

Large workpieces which cannot be clamped in a chuck are mounted in a faceplate where they are held by clamps, blocks, spacer rods and bolts (Fig. 20*d*) or on an angle plate (Fig. 20*e*) or in a special fixture clamped on the faceplate.

Lathe tools (see Fig. 3) are clamped either in a tool post or a *square turret* (Fig. 26) that can hold four tools at one time and enables them to be put into operation consecutively with a minimum loss of time. The turret can be indexed through 90° and reclamped in the new position with a single lever *2*. When the lever is turned in direction *a*, shaped nut *1* first releases the turret and then tooth *4* engages one of the spring-loaded pins *5* and indexes the turret. Locking pin *3* properly locates the turret in each position. When lever *2* is turned in the other direction (*b*), the turret is reclamped on the tool slide and the tooth of the nut slips over the next pin, thereby preparing the turret for the next indexing motion.

Drills, reamers and other tools are clamped in the tailstock spindle in the same manner as they are held in the spindle of a drill press.

2-10. Setting Up an Engine Lathe for Various Jobs

Setting up is done to prepare a machine tool for performing a definite operation or job. For the purposes of this text, setting up will be divided into tooling and adjustment.

Tooling, in the sense accepted here, consists in properly mounting and clamping the cutting tools in the corresponding fixtures and attachments on the machine tool, in setting up and clamping the work directly in the machine tool or in a fixture, in lubricating the machine before starting operation, in arranging the facilities for delivering the cutting fluid to the working zone, and in performing certain other preparatory operations.

Adjustments, insofar as they concern setting up, consist in preparing the machine tool kinematically to perform the machining operation in accordance with the selected or specified cutting speeds and feeds. For this purpose, adjustments are made in the kinematic chains of the machine tool, setting the control devices of the main drive speeds and the rates of feed to the required positions. It is often necessary to calculate the gearing ratios of the gear trains that are to be adjusted and then to obtain these ratios with the aid of speed and feed gearbox levers, by switching over a multiple-speed motor, adjusting the speed of a variable-speed motor, installing the required change gears, interchangeable cams, templates, etc.

In the general case, to set up an engine lathe it will be necessary to determine by calculations: the required transmission ratio of the unit for setting up the speed gear train to obtain the given spindle speed, and required ratio of the unit for setting up the feed gear train to obtain the given feed or given pitch of threads being cut (see below)

No calculations whatsoever are needed in setting up (adjusting) the speed gear train of a modern engine lathe. This can be done by simply shifting the speed gearbox levers (for example, *1* and *4* in Fig. 7) to the positions corresponding to the required spindle speed. Time is saved by providing a speed index plate on the lathe indicating the lever positions for each spindle speed. If spindle speeds are infinitely variable, the actual spindle speed at any time is indicated by the hand of an instrument with a scale graduated in spindle rpm.

In lathe operations the feed motion is transmitted by the feed rod to the carriage saddle or cross slide. The required feed per spindle revolution is obtained by shifting levers without any calculations being needed. All the available feed values have been calculated beforehand and are provided in the form of tables which facilitate setting up the required rate The feed mechanism, for example, of the model 1K62 lathe provides 42 different longitudinal feeds in a range from 0.07 to 4.16 mm per revolution, and the same number of cross feeds in a range from 0.035 to 2.08 mm per spindle revolution.

TABLE 5

Operations	Quadrant change gears	Clutch engagements (see Fig. 6)				
		C_2	C_3	C_4	C_5	C_8
Turning and boring	42 : 50		+	+		+
Cutting threads:						
Metric threads	42 : 50		+			+
English threads	42 : 50	+	+		+	
Module worm threads	64 : 97		+			+
Diametral pitch worm threads	64 : 97	+	+		+	
Any threads, by-passing the feed gearbox	Determined by calculation				+	+

In cutting threads two setting-up units are employed: the quick-change feed gearbox and the change-gear quadrant. Changes are made in the latter only when a different type of threads is to be cut (Table 5). The change gears required for this purpose are furnished with the lathe. Most standard threads can be cut by shifting the cluster gears of the feed gearbox and installing the required change gears on the quadrant. The following threads can be cut in the model 1K62 lathe (without using the coarse thread unit): metric threads with pitches from 1 to 12 mm; English threads with 2 to 24 tpi (threads per inch); module worm threads with a module from 0.5 to 3 mm; and worm threads with a diametral pitch from 96 to 7.

Threads with larger pitch can be cut if the coarse thread unit is used. In the spindle speed range from 12.5 to 40 rpm this unit can increase the pitch 32-fold in relation to the indicated values, and 8-fold in the range from 50 to 160 rpm of the spindle. The thread pitch is set up with a single star wheel while the coarse pitch unit is engaged by turning knob *2* (Fig. 7).

The thread-cutting gear train of an engine lathe is shown schematically in Fig. 27 where the diamond-shaped symbols denote the setting-up units, namely the change-gear quadrant, feed gearbox and coarse pitch unit with gearing ratios of i_q, i_f and i_{cp}, respectively. In the general case, the feed gear train can also incorporate transmissions with a constant total gearing ratio of p.

The setting-up units of the thread-cutting gear train must be calculated and set up so that the longitudinal travel of the carriage per spindle revolu-

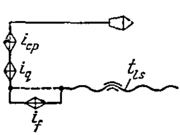


Fig. 27. Schematic diagram of the feed gear train in an engine lathe

tion exactly coincides with the pitch* P of the thread to be cut. The equation of kinematic balance, linking together the motions of the final links of the kinematic chain, can be written as follows:

$$1_{sp\ rev} p i_{cp} i_q i_f t_{ls} = P \tag{4}$$

from which we obtain the formula for determining the required ratios for the setting-up units. Thus

$$i_{cp} i_q i_f = \frac{P}{p t_{ls}} \tag{5}$$

The pitch P of the thread to be cut and the pitch t_{ls} of the lead screw should be specified in the same units of measurement.

Threads not provided for by the feed mechanism of the lathe and threads with nonstandard pitches can be cut with a special set up of the change-gear quadrant, either with or without the use of the feed gearbox mechanism.

First method. In cutting threads with a pitch P_{tab}, provided for by the lathe feed mechanism, the change-gear quadrant, coarse thread unit and the feed gearbox have definite gearing ratios i_q^0, i_{cp}^0 and i_f^0.

Thus, formula (5) can be written as

$$i_{cp}^0 i_q^0 i_f^0 = \frac{P_{tab}}{p t_{ls}} \tag{6}$$

If it is necessary to cut a thread with a pitch P_{th} that differs from P_{tab} then, without changing the value of i_f^0 and i_{cp}^0, the gearing ratio i_q of the change-gear quadrant must be altered Thus

$$i_{cp}^0 i_q i_f^0 = \frac{P_{th}}{p t_{ls}} \tag{7}$$

After dividing the members of equation (7) by those of equation (6) we obtain the setting-up formula for cutting thread with the pitch P_{th}

$$i_q = i_q^0 \frac{P_{th}}{P_{tab}}$$

*In cutting multiple-thread (multiple-start) threads, the gear train is set up to the *lead* of the thread which is equal to the product of the pitch and the number of starts

Inch thread is specified not by the pitch P, but by the number of threads per inch n. Thus

$$P = \frac{25.4}{n} \text{ mm} \tag{8}$$

Module worm thread is specified by the module m in mm and its pitch is

$$P = \pi m \text{ mm} \tag{9}$$

Diametral pitch worm thread is specified by the diametral pitch DP and its pitch is

$$P = \frac{25.4\pi}{DP} \text{ mm} \tag{10}$$

In the case of the model 1K62 engine lathe (see Table 5), the various equations for setting up the change-gear quadrant, making use of the feed gearbox, can be written as follows:

metric threads

$$i_q = \frac{42}{50} \frac{P_{th}}{P_{tab}}$$

inch threads

$$i_q = \frac{42}{50} \frac{n_{tab}}{n_{th}}$$

module worm threads

$$i_q = \frac{64}{97} \frac{m_{th}}{m_{tab}}$$

diametral pitch worm threads

$$i_q = \frac{64}{97} \frac{DP_{tab}}{DP_{th}}$$

Second method. If the feed gearbox is excluded from the feed gear train, the equation of kinematic balance (4) is changed to

$$p i_q i_{cp} t_{ls} = P$$

then

$$i_q = \frac{P}{p t_{ls} i_{cp}}$$

If on the engine lathe the lead screw has a metric thread, the setting-up formulas for the change gears in cutting various types of threads will be

$$\left.\begin{aligned}
&\text{metric threads} && \text{inch threads} \\
&i_q = \frac{P_{th}}{p t_{ls} i_{cp}} && i_q = \frac{25.4}{p t_{ls} n_{th} i_{cp}} \\
&\text{module worm threads} && \text{diametral pitch worm threads} \\
&i_q = \frac{\pi m_{th}}{p t_{ls} i_{cp}} && i_q = \frac{25.4\pi}{p t_{ls} DP_{th} i_{cp}}
\end{aligned}\right\} \tag{11}$$

The gearing ratio, calculated from the pertinent formula, must be set down as the ratio of the number of teeth on the change gears of the quadrant

(see Fig. 12)

$$i_q = \frac{A}{B} \times \frac{C}{D}$$

where A, B, C and D are the numbers of teeth on the change gears.

Special tables are available to facilitate the selection of change gears to obtain a definite given gearing ratio.

The following inequalities are used to check whether the selected change gears can be installed on the quadrant and will properly mesh:

$$A + B > C + (15 \text{ to } 20)$$
$$C + D > B + (15 \text{ to } 20)$$

These formulas ensure that gear B does not interfere with shaft *5* and gear C with shaft *7*. Depending upon the construction of the quadrant, it is also necessary that the sums of the numbers of teeth $(A + B)$ and $(C + D)$ exceed a definite value as otherwise the pairs of gears cannot be meshed together.

More accurate threads can be cut if the lead screw is linked directly to the last shaft of the change-gear quadrant since, in this case, all extra links (gears, clutches, etc.) are excluded from the gear train. Such links may reduce the rigidity of the feed gear train and lead to pitch errors in the thread being cut.

Scrolls, having the form of an Archimedean spiral, are cut by power feed of the cross slide *2* (see Fig. 13) driven from the feed rod.

To reverse the feed simultaneously with a reversal in spindle rotation, cluster gear CG_{13} (see Fig. 6) is shifted to the left to mesh with gear $56T$ which is rigidly mounted on feed rod XVI. The change gears required to cut thread of the given pitch can be calculated by one of the formulas (11).

In cutting multiple threads (a triple thread is shown in Fig. 28) the lead S of the thread (the *pitch of the thread helix*) is to be used in the setting-up formula (4) instead of the thread pitch P Thus

$$S = kP$$

where k is the number of starts.

All the starts of a multiple thread can be cut by indexing the work through $\frac{1}{k}$ of a revolution in reference to the stationary tool to cut each successive start. This operation can be done, for example, with a special indexing faceplate (Fig. 29) comprising two parts. Member *1* is mounted on the spindle nose and member *2* with the driving stud *4* can be turned to the required position with respect to member *1* and clamped with T-bolts *3*. An index mark is engraved on the cylindrical outside surface of the stationary member and a scale on the adjustable member. This enables the angle

through which the work is indexed in reference to the stationary spindle to be read off with sufficient accuracy for ordinary purposes.

Indexing is carried out in the model 1K62 lathe by turning the spindle when the thread-cutting gear train is disconnected by shifting cluster gear CG_6 (Fig. 6) out of mesh and into the neutral position. The angle through which the spindle is indexed is read off on a scale engraved on its rear end. The spindle gear and the cluster gear with which it meshes have 60 teeth each so that they can be brought back into mesh when dividing a circumference into 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 or 60 parts.

Another method has been devised by lathe operator N. Smirnov for indexing in cutting multiple threads (Fig. 30). It consists in axial adjustment of the threading tool, the work being stationary, by an amount equal to the pitch of the thread being cut. This is done by traversing the compound rest. Clamped in the square turret is dial indicator *2* whose contact point touches gauge block *1*. By using two gauge blocks with a difference in size equal to the pitch, the tool can be accurately shifted from start to start.

The use of a multiple-tool holder (Fig. 31) enables machining time to be reduced in cutting multiple thread because all the starts are cut simultaneously.

Two, three or more threading tools, spaced at distances equal to the thread pitch, are set up in the holder to a template gauge.

High-velocity chasing of external or internal threads can be performed in an engine lathe with special rotary tool heads running at high speed. The rotary tool head *1* (Fig. 32), in which one or several tools *2* are clamped, is mounted on the lathe carriage eccentrically in relation to the work *3* and is rotated at high speed (1,000 to 3,000 rpm) by a separate motor. The work rotates at a substantially lower speed (3 to 40 rpm). The thread-cutting gear train must be set up so that the carriage travels a distance equal to the thread pitch during each revolution of the work. In this thread-chasing procedure each threading tool contacts the work only during a short period of time, i.e., only over a part of the work circumference. The tool cuts a fine comma-shaped chip and during the remainder of each revolution moves through air. This very effectively cools the tool and permits the cutting speed to be considerably increased, thereby increasing the output as well. Internal threads are chased by this method using a rotary holder with a threading tool (Fig. 33). Using such a tool head or holder, thread with a pitch up to 6 mm can be cut in a single pass.

Tapered surfaces are turned in a lathe by one of the following methods: (1) setting over the tailstock, (2) swivelling the compound rest, (3) using a taper-turning attachment, or (4) using two feeds.

First method. The body of the tailstock is set over crosswise by an amount equal to h in reference to the base (Fig. 34). Consequently, the axis of the work mounted between centres makes a certain angle α with the direction

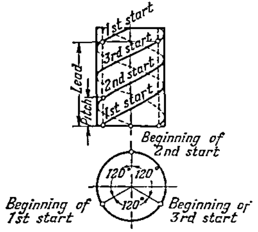


Fig. 28. Triple thread

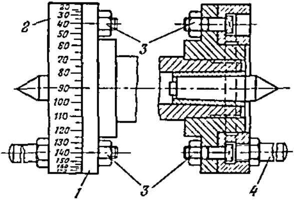


Fig. 29. Indexing faceplate for cutting multiple threads

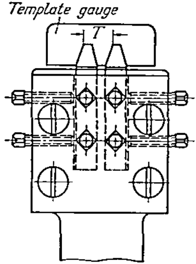


Fig. 31. Holder for cutting double threads

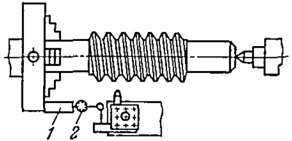


Fig. 30. Indexing in cutting multiple threads by axial adjustment of the chasing tool

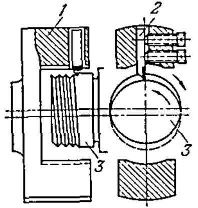


Fig. 32. Cutting external thread with a rotary tool head

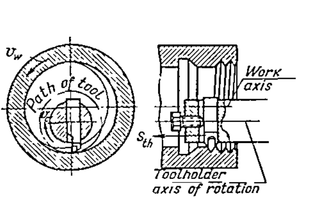


Fig 33. Cutting internal thread with a rotary toolholder

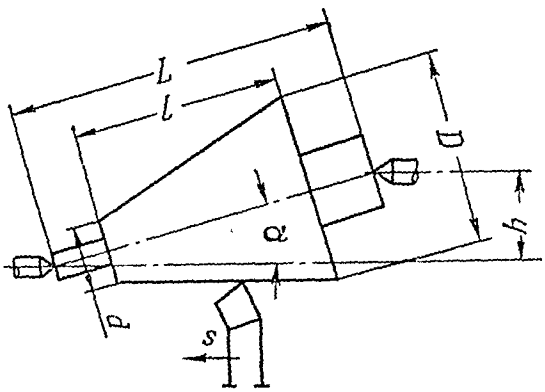


Fig. 34. Turning a taper by setting over the tailstock

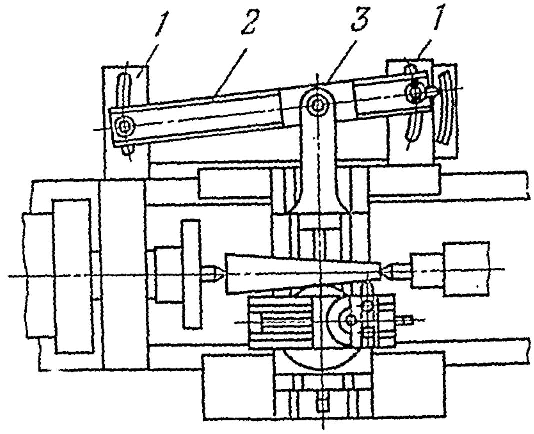


Fig. 35. Taper turning attachment

of longitudinal feed of the carriage. It follows from the diagram in Fig. 34 that

$$\frac{h}{L\cos\alpha}=\frac{D-d}{2l}=\frac{k}{2}$$

where $k=\frac{D-d}{l}$ is the taper of the surface to be turned. Therefore, the set-over of the tailstock to obtain a taper of $k=2\tan\alpha$ is

$$h=k\frac{L\cos\alpha}{2} \tag{12}$$

This method can be applied for turning surfaces with a relatively small taper (up to about 1 : 4) and when the accuracy requirements are not particularly high since the misaligned position of the centres in the centre holes leads to rapid wear of the latter and loss of locating accuracy.

Second method. This procedure involves swivelling the compound rest through an angle α in reference to the line of centres of the lathe and feeding the tool either by hand or power (in heavy-duty lathes). This method is suitable for turning accurate internal and external tapers of a length limited by the travel of the compound rest.

Third method. This method requires that a special device called a *taper turning attachment* be installed on the engine lathe.

The simplest type of taper attachment is shown in Fig. 35. It consists of a guide bar *2* secured on brackets *1* which are bolted to the rear side of the bed. The guide bar can be set to the required taper angle α in reference to the line of centres of the lathe. Guide block *3*, sliding along the guide bar, is linked to the cross slide. The latter is disconnected from the saddle by removing the cross feed screw. If the carriage travels with longitudinal feed along

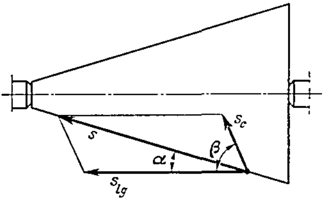


Fig. 36. Turning a taper by the two feeds method

the bed, a cross movement, due to the travel of block *3* along bar *2*, is transmitted to the tool in addition to its longitudinal movement. The resulting motion of the tool will be at an angle α to the axis of the work, this angle being equal to that at which the guide bar is set. More universal taper attachments are available which permit the tool to pass over automatically from turning a cylindrical part of the workpiece to a tapered section.

Taper turning attachments enable accurate tapers with an angle up to 15° or 18° to be turned. The length of the taper must not exceed that of the guide bar.

Fourth method. Taper turning by means of two feeds is limited to lathes having power feed of the compound rest, and the possibility of engaging this feed simultaneously with longitudinal feed of the carriage. In the main, these are heavy-duty lathes, for example, models 163, 1660, 1660Г and others. The resultant feed of the tool (Fig. 36) in reference to the line of centres will be the geometrical sum, in the given case, of the longitudinal feed s_{lg} of the carriage and the feed s_c of the compound rest which is set at an angle β to the line of centres. Thus

$$\overrightarrow{s} = \overrightarrow{s}_{lg} - \overrightarrow{s}_c$$

According to the sine law

$$\frac{s_{lg}}{\sin(\beta - \alpha)} = \frac{s}{\sin\beta} = \frac{s_c}{\sin\alpha}$$

from which the setting angle of the compound rest is

$$\beta = \alpha + \arcsin\left(\frac{s_{lg}}{s_c}\sin\alpha\right)$$

Since in most engine lathes

$$\frac{s_{lg}}{s_c} = \Delta = \text{const}$$

the setting angle of the compound rest can be written as

$$\beta = \alpha + \arcsin(\Delta \sin \alpha)$$

If s is the required feed along an element of the taper, then the rate of longitudinal feed should be

$$s_{lg} = s\frac{\sin(\beta - \alpha)}{\sin \beta}$$

The two-feed taper turning procedure enables tapers to be turned having elements of a length longer than the travel of the compound rest.

2-11. Attachments Extending the Processing Capacities of Engine Lathes

Various attachments, such as contouring, reproducing, milling, grinding and high-speed drilling attachments; tailstocks with turret attachments; attachments for boring, slotting, cutter-relieving, etc., considerably widen the versatility of a lathe and enable work to be machined with various types of cutting tools without resorting to other machine tools. This reduces time lost in setting up, clamping, unloading and handling workpieces, and increases the utilization factor, a feature of especial importance in the use of heavy-duty lathes.

The use of tracer-controlled contouring attachments enables surfaces of rotation of irregular shape and stepped shafts to be turned with minimum labour input.

The simplest type of tracer-controlled contouring device is similar to that shown in Fig. 35 in which the straight guide bar *2* has been replaced by a template of the required shape and guide block *3* by a roller or stylus.

A mechanical tracer-controlled attachment designed by V. Seminsky for turning stepped shafts, tapers and contoured surfaces is shown in Fig. 37. Body *3* of the attachment is mounted on the lathe carriage in place of the square turret or tool post, and travels at a definite rate of longitudinal feed. Holder *1*, carrying tool *2*, is mounted with a sliding fit in a bore of body *3*, at an angle to the line of centres. Under the action of spring *6*, stylus *4* of the holder bears tightly against the profile of template *5*. To prevent its axial movement the template is secured to a bracket mounted on the lathe bed. The holder is advanced by means of eccentric cam *7* for returning the carriage to its initial position after removing the turned workpiece.

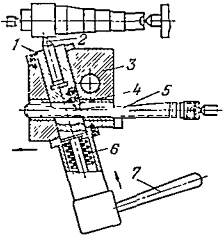


Fig. 37. Tracer-controlled turning attachment designed by V. Seminsky

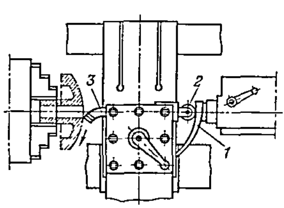


Fig. 38. Machining a spherical surface

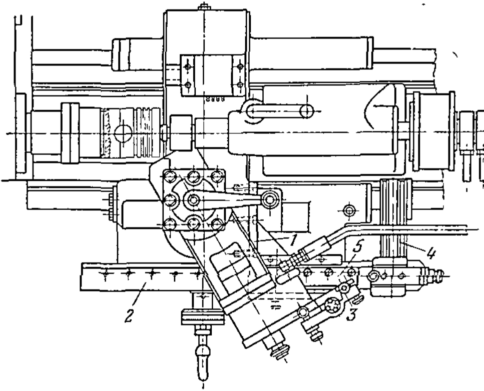


Fig. 39. Hydraulic tracing slide, model ГС-1, mounted on an engine lathe

An attachment for turning spherical surfaces (Fig. 38) operates by a similar principle. Template *1* is clamped in this case in the tailstock spindle. If cross feed is transmitted to the cross slide, roller *2* clamped in the square turret, as well as tool *3*, will reproduce the profile of template *1*.

Disadvantages of mechanical duplicating are the difficulties in making a template sufficiently accurate and strong enough to withstand the cutting force, and the rapid wear of such templates.

Up-to-date engine lathes are equipped with special hydraulic or electric tracer-controlled contouring devices which are lot-produced at Soviet machine tool plants.

Figure 39 illustrates the hydraulic tracing slide, model ГС-1, designed at the Krasny Proletary Plant. It is to be mounted on the cross slide of the lathe in place of the swivel base and compound rest. Bracket *1*, secured to the cross slide, has a slot parallel to the line of centres of the lathe. Bar *2*, sliding in this slot, is held against axial movement by a roller which enters a crosswise slot in bracket *4* mounted rigidly on the lathe bed. Template *5*, along whose profile stylus *3* of the tracing slide travels, is fastened by screws to bar *2*.

The hydraulic system of this slide (Fig. 125, Vol. 2) maintains a constant distance between the nose of the cutting tool and that of the stylus sliding along the profile of the template. Therefore, the nose of the tool duplicates the profile of the template.

An electric tracing device consists of an electric tracing head secured rigidly on the cross slide of the lathe. Upon longitudinal feed of the carriage, the stylus of the tracing device slides along the profile of a stationary template. Special electromagnetic clutches are provided in the apron for engaging, disengaging and reversing the cross feed. As the saddle travels along the bed ways the template deflects the stylus. This closes contacts in the tracing head and transmits a command to engage the electromagnetic clutch which provides feed of the cross slide in the direction restoring the neutral position of the stylus. Thus, in this case as well, the system maintains a constant distance between the nose of the tool and the tip of the stylus.

The chief advantage of nonmechanical tracing systems is that the stylus sliding over the template profile does not carry the cutting force. It only transmits commands to the operative unit (hydraulic cylinder or electromagnetic clutches) which effects the working feed of the tool. Because of the low pressure of the stylus on the template and the comparatively small size of the stylus, it proves feasible to turn steep transition surfaces of the contour at higher speeds and feeds, and to use templates made of inexpensive materials.

The milling attachment shown in Fig. 40 can be used to perform milling operations in an engine lathe. Holder *1* is clamped in the tool post of the lathe. Swivelling member *2* of the attachment has ways and can be turned

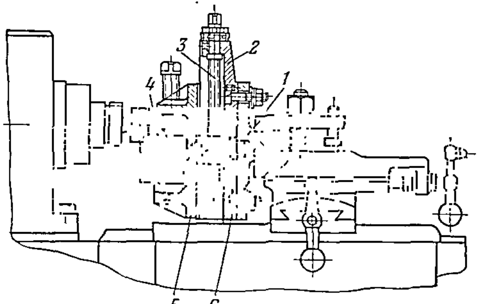


Fig. 40 Milling attachment

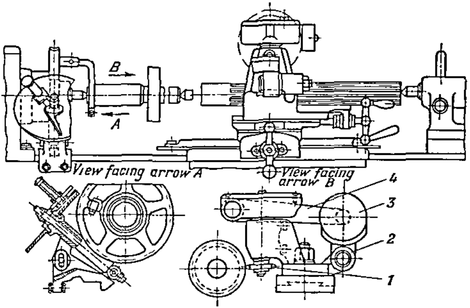


Fig. 41. Attachment for milling spline shafts and gears

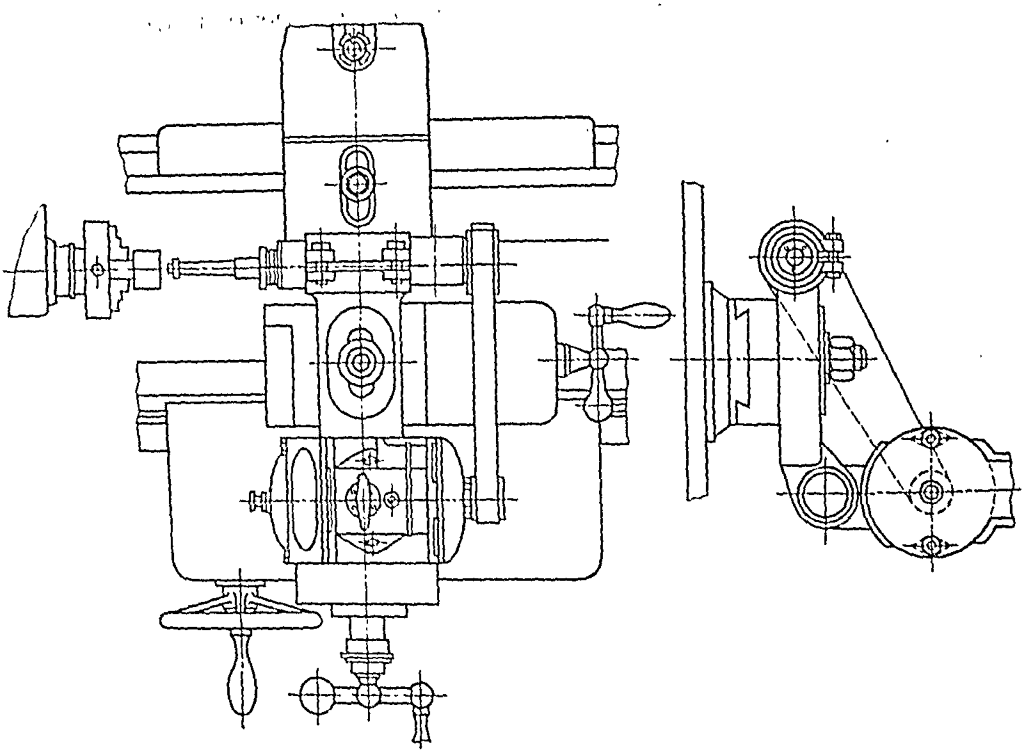


Fig. 42. External and internal cylindrical grinding attachment

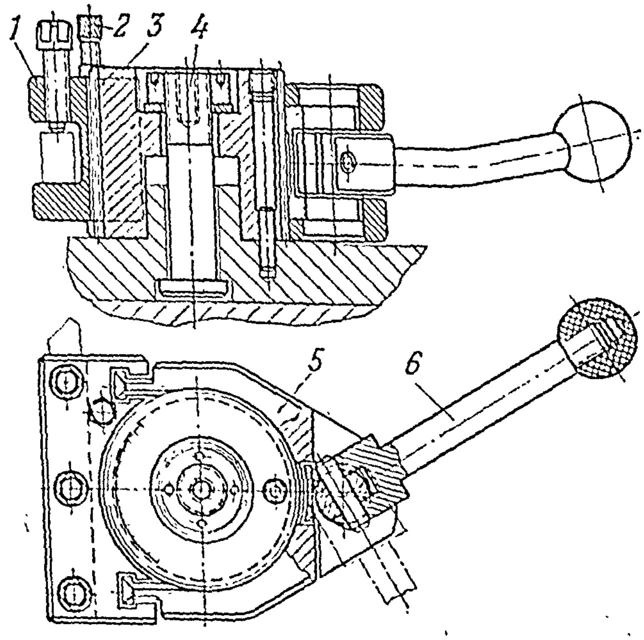


Fig. 43. Rapid-change toolholder

to the required position in respect to the holder and be clamped with screws *6*. Lead screw *3* moves slide *5*, in which work *4* is clamped, along the ways of member *2*. The milling cutter is mounted in the taper hole of the lathe spindle. The work is set to the depth of cut and the working feed is provided either by the cross slide of the lathe or by turning the feed screw of the attachment.

Spline shafts and gears can be milled by an attachment (Fig. 41) mounted on the lathe carriage in place of the tool post or square turret. The milling spindle with cutter *1* is powered from a separate motor *3* through a belt drive *4* with change pulleys. The belt is tensioned by rotating the drive motor about pivot *2*.

The work can be indexed for cutting the next spline or tooth space by a method described in Sec. 2-10 or by the use of a special dividing head (see Sec. 8-3).

Internal and external grinding operations can be performed with the attachment shown in Fig. 42.

The square turret, widely used at the present time on engine lathes, limits the number of tools that can be clamped simultaneously on the carriage. Quick-change toolholders with interchangeable holding members permit the lathe to be equipped with a great variety of tools whose setting up entails a minimum loss of time. One construction of a rapid-change toolholder is illustrated in Fig. 43. Here wide gear *3* is mounted on the compound rest of the lathe and secured by bolt *4*, a nut and a dowel pin.

The interchangeable holding member *1* has internal gear teeth cut on one side which fit the tooth spaces of gear *3*. Yoke *5* serves to clamp the holding member; its T-shaped lugs enter T-slots in the holding member. With the aid of eccentric-action lever *6* the holding member is securely clamped to the gear. The tool is adjusted in height by means of screw *2*.

2-12. Mechanisms Increasing the Degree of Automaticity of Engine Lathes

The degree of automaticity in controlling the working cycle is quite low in general-purpose engine lathes.

In nonautomatic machine tools approximately 25 to 30 per cent of the floor-to-floor time is used to set up and clamp the work, an operation requiring, moreover, a definite physical effort on the part of the operator. The application of power-operated clamping facilities allows this time to be reduced 8- to 10-fold with a minimum expenditure of hand labour (pushing a button, turning a lever, etc.).

Power-operated work clamping is accomplished in most cases by employing special pneumatic or hydraulic chucks. Figure 44 illustrates a power chuck

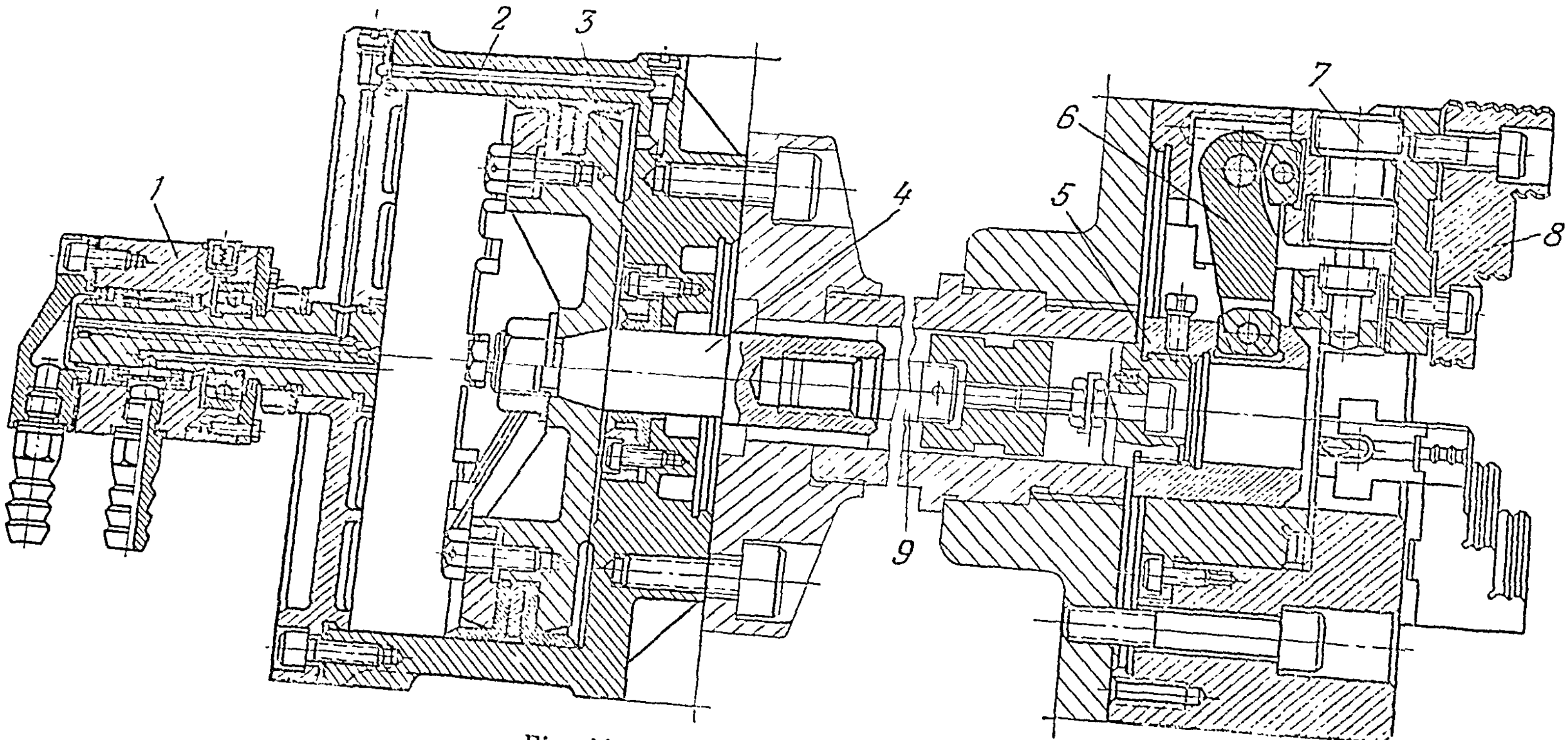


Fig. 44. Three-jaw pneumatic chuck

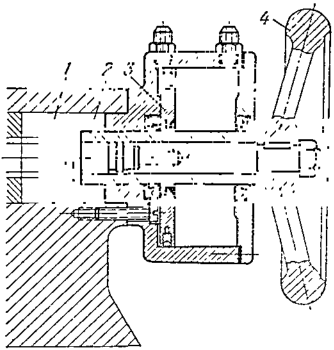


Fig. 45. Air cylinder for operating a tailstock spindle

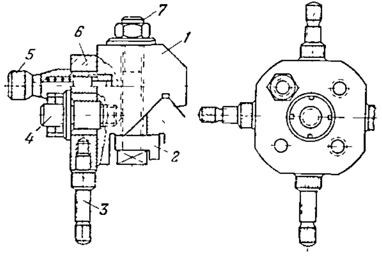


Fig. 46. Multiple-position positive stop

whose rotating air cylinder is mounted on the rear end of the spindle. By turning the handle of a cock mounted on the lathe, compressed air is admitted from the shop mains, through stationary connection *1* on a revolving joint, into the right or left end of air cylinder *2*, to move piston *3* with its rod *4*. Draw rod *9*, passing through the hole in the spindle, links piston rod *4* to sleeve *5* of the chuck. Axial motion of the sleeve turns angle levers *6* to spread or draw together jaws *8*. The jaws can be adjusted to the diameter of the work they are to clamp by using screws *7*. The lathe is automatically stopped if the pressure in the compressed air mains drops below the permissible value.

Air cylinder *3* (Fig. 45) can be used to mechanize the movement of a tailstock spindle. Piston *2* of this double-action cylinder moves the screw *1* of the tailstock spindle. Rough settings of the tailstock spindle are made with handwheel *4* which rotates the screw in the piston sleeve.

Various devices are in wide use for automatically stopping the carriage and for switching off the lathe when the required size is reached in various operations (operating to positive stops). A multiple-position stop, limiting longitudinal travel of the carriage, is shown in Fig. 46. Body *1* of this stop is clamped by strap *2* and bolts *7* to the front way of the bed.

Disk *6* with stop screws *3* of adjustable length can be indexed on pivot *4* by means of handle *5*. The disk can be locked in each of its four indexed positions. When the carriage reaches the positive stop, a safety device is tripped in the apron which disengages the feed gear train. Stops of similar design are used to limit the travel of the cross slide. This arrangement enables work to be accurately turned to the given diameters without resorting to the dial scales of the carriage or to measuring tools.

The use of carriage and cross-slide stops mechanizes the turning of workpieces of the stepped shaft type.

The application of loading and unloading devices (their construction is considered in Vol. IV, Part Six) in conjunction with mechanized work clamping and automation of the controls enables a general-purpose engine lathe to be converted into an automatic and to be built into a transfer machine.

2-13. Plain Turning Lathes

Universal plain turning lathes differ from engine lathes in that they do not have a lead screw. They are used to perform lathe work of all kinds except for the chasing of threads with a single-point tool (heavy-duty lathes are an exception).

The dimensional data for plain turning lathes are similar to that of engine lathes.

Lathes of small sizes (to a maximum diameter of workpiece of 130 mm) are available as above-standard or high-accuracy bench lathes.

In the medium-size models, the basic parts (bed, headstock, tailstock, carriage, etc.) of the corresponding sizes of engine lathes are used. Such plain turning lathes are intended chiefly for turning work of the stepped shaft type in lot production. In this sense, they can be considered to be single-purpose lathes. Such lathes may be equipped with attachments for tracer-controlled duplicating, for automatic loading and unloading, and for automatic control of the working cycle (sometimes with numerically controlled systems) that convert them into automatics. Lathes of above-standard accuracy are also manufactured using engine lathes as the basic models.

Heavy-duty lathes are available only as the universal plain turning type. They can be equipped with various attachments that extend their processing capacities, enabling them to machine heavy work with various types of cutting tools without resorting to other machine tools.

The principal dimensional data of certain models of Soviet plain turning lathes are listed in Table 6.

TABLE 6

Model	Maximum workpiece diameter × distance between centres, mm	Speeds of main drive, rpm	Available power, kW	Net weight, kg *approx.*
1600	100 × 125	600 to 6,000	0.12	25
1Б601	125 × 180 (250)	470 to 5,300	0.45/0.6	190 (200)
1Д603	160 × 250	56 to 3,160	0.8	500
1Д604	200 × 350	353 to 3,000	1.1	480
16T11	250 × 350 (500)	50 to 2,500	4	100 (125)
16T16	320 × 500 (710, 1,000)	40 to 2,000	7 5	1350 (1,500; 1,650)
16T20	400 × 710 (1,000, 1,400)	32 to 1,600	7 5 or 10	2,100 (2,200; 2,400)
16T25	500 × 1,000 (1,400, 2,000)	50 to 2,500	13	2,650 (3,000, 3,300)

2-14. Features of Plain Turning Lathes

The construction arrangement and principal units of universal plain turning lathes are the same as those of engine lathes (Fig. 4).

The absence of the lead screw substantially simplifies the kinematic features and the construction of the feed gear trains of the lathe since there

is no need for mechanisms so typical of engine lathes as the gear cone and tumbler gear of the feed gearbox and the half-nuts in the apron. Power feed of the carriage may also be absent in small-size lathes, all movements of the tool in relation to the work being manual.

As a rule, heavy-duty lathes have several carriages which are powered either from a common feed rod, linked kinematically to the lathe spindle, or from variable-speed d-c motors (Fig. 47) mounted on each carriage.

The compound rests of the carriages have a power feed. If the carriage is powered from a feed rod, short metric or English threads (not longer than the travel of the compound rest) can be cut.

The tailstock and steady rests of a heavy-duty lathe can be traversed along the bed ways by a drive powered from an individual motor. The tailstock spindle is similar in design to the headstock spindle and runs in antifriction bearings. It has a separate drive for positioning motions. A faceplate mounted on the end of the tailstock spindle enables long and heavy workpieces to be more reliably clamped.

2-15. Facing Lathes

Facing lathes (Fig. 48) are single-purpose machines intended for turning work of large diameter but short length. They perform such operations as turning external cylindrical and taper surfaces, facing, cutting grooves, boring, etc.

In construction, a facing lathe differs to some extent from a centre lathe and consists of the following main units (Fig. 48): baseplate *1*, headstock *4* with faceplate *5*, bed member *2*, carriage *3* and tailstock *6* mounted on a high support. The headstock which houses the speed gearbox is secured rigidly to the baseplate. The bed member with its longitudinal ways and the tailstock can be positioned as required on the baseplate and clamped by T-bolts whose heads enter T-slots of the baseplate.

The work is clamped on the faceplate either by the jaws or with the aid of strap clamps and bolts. If necessary, the work can be additionally supported by the tailstock centre. The gap in the baseplate, immediately under the faceplate, allows work of a diameter larger than that of the faceplate to be turned.

The feed gear train is powered from a separate motor and provides for a wide range of power feeds in both the longitudinal and transverse directions.

Table 7 lists the principal dimensional data for facing lathes manufactured in the USSR. Facing lathes have been almost completely superseded by vertical turning and boring mills. Because of their simple construction and comparatively low cost, however, they are still employed in piece production and for repair jobs.

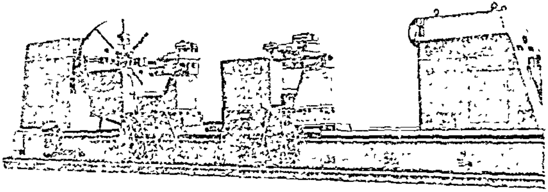


Fig. 47. Plain turning lathe, model 1683T

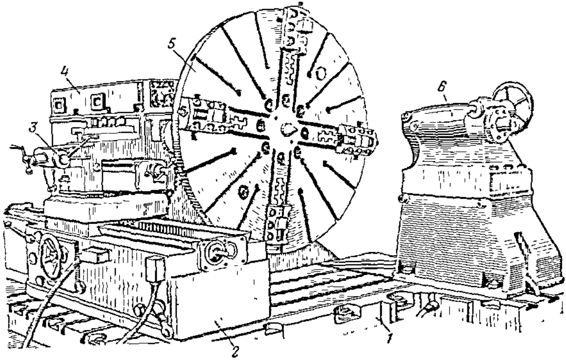


Fig. 48. Facing lathe, model 1693

TABLE 7

Model	Diameter of work accommodated, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.	Remarks
1690	800	4 to 800	17	8,000	Incorporate device for maintaining constant cutting speed, power chuck, tracer-controls, infinitely variable speeds and feeds
1A691	1,250	2.5 to 315	17 or 22	14,000	
1A692	2,000	1 to 100	30	17,000	
1A693	3,200	0.8 to 63	30	—	
1A695	5,000	0.63 to 50	40	—	
1A698	8,000	0.5 to 40	55	—	

2-16. Multiple-Tool Lathes

Multiple-tool lathes are single-purpose high-production machines intended for turning work such as stepped shafts, cluster gears, etc. (between centres or in a chuck) in lot and mass production shops.

Figure 49 shows a multiple-tool setup for turning a stepped shaft. The provision on multiple-tool lathes of two or more carriages, each carrying several single-point tools operating simultaneously, enables the machining

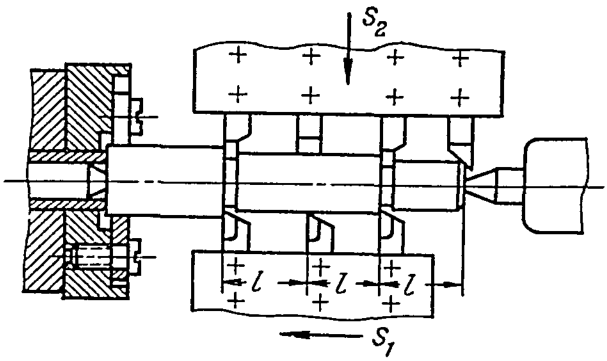


Fig. 49. Setup for turning a stepped shaft in a multiple-tool lathe

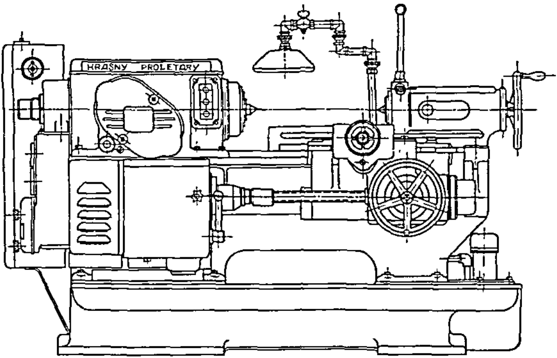


Fig. 50. Multiple-tool semiautomatic lathe

time to be reduced since the travel of each tool is only a part of the full length of the blank, and because the carriages operate simultaneously. The front carriage mounts the tools for turning the steps of the shafts and travels with the longitudinal working feed s_1. The rear carriage has only the cross feed s_2 and is used to cut grooves, face shoulders, turn chamfers and short contoured surfaces with form tools.

Multiple-tool lathes operate on a semiautomatic cycle. The operator only *sets up the blank, starts the lathe and removes the finished work*. This feature allows one operator to handle several machine tools simultaneously (*multiple machine tool handling*).

The construction of multiple-tool lathes is distinguished for the exceptionally high rigidity of such units as the bed, carriages, headstock and tailstock. This is necessitated by the large total chip cross section when the stock is removed simultaneously by several tools.

Figures 50 and 51 illustrate the general view and gearing diagram of the multiple-tool semiautomatic lathe. The spindle is powered by

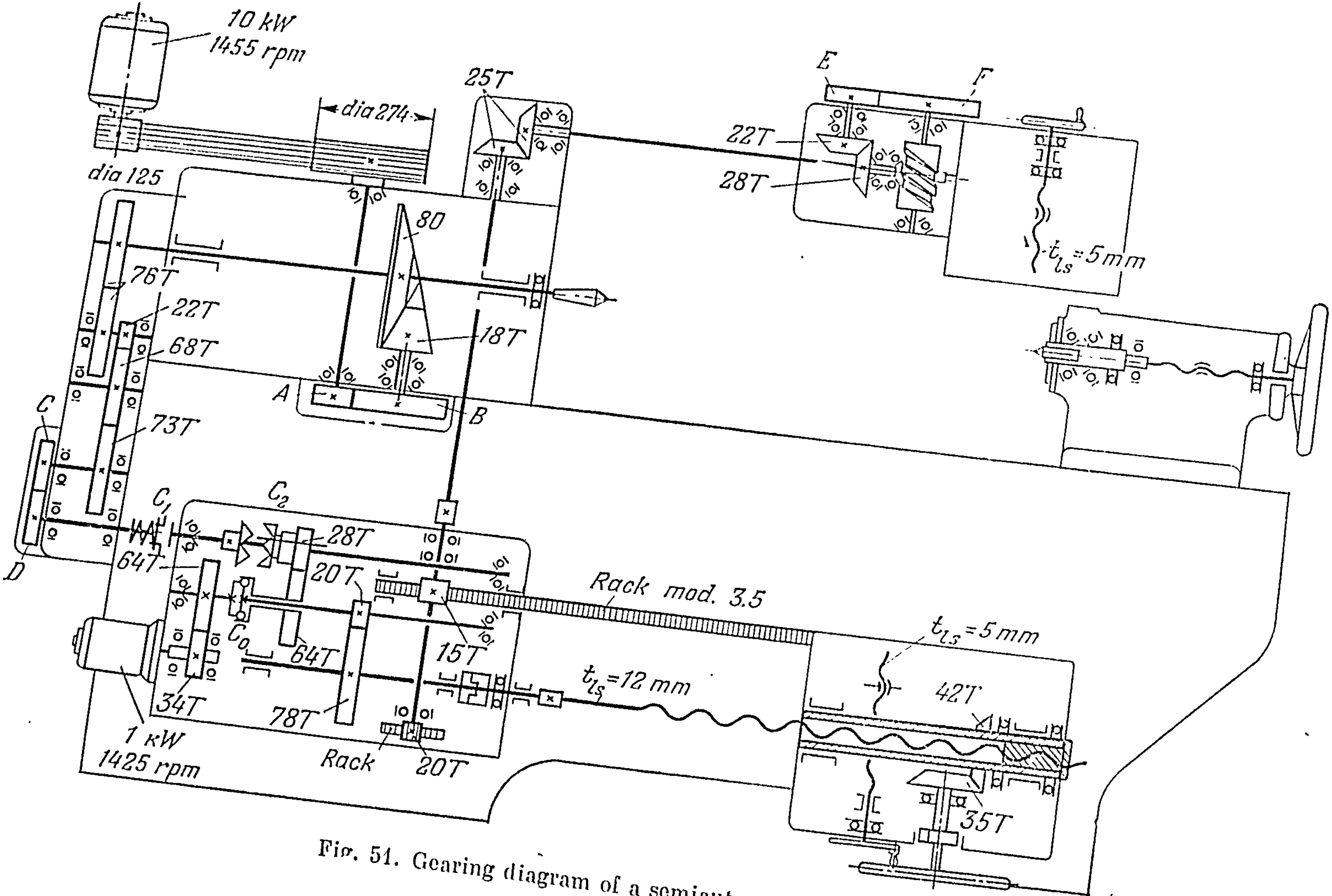


Fig. 51. Gearing diagram of a semiautomatic lathe

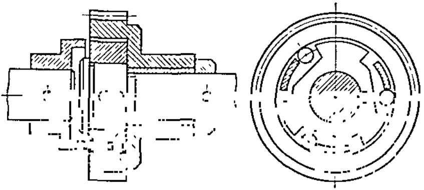


Fig. 52. Two-direction overrunning clutch

a 10-kW motor through a V-belt drive, change gears A and B, and bevel gearing $18:80$.

A set of 12 change gears provides for 12 different spindle speeds in the range from 40 to 500 rpm.

The feed gear trains for the front and rear carriages are driven from the spindle. The gear train to the front carriage includes the following elements: gears $\frac{76}{76} \times \frac{22}{73}$, change gears $\frac{C}{D}$, safety clutch C_1, feed disengagement clutch C_2, gears $\frac{28}{64}$, two-direction overrunning clutch C_0 (Fig. 52), gears $\frac{20}{78}$, and lead screw $t_{ls} = 12$ mm. The eight available feed change gears $\frac{C}{D}$ enable 8 different longitudinal feeds in the range from 0.12 to 1.38 mm per revolution to be transmitted to the front carriage.

The feed gear train of the rear carriage is driven from a gear rack with a module of 3.5 mm fastened rigidly to the front carriage. In its movement the rack rotates a pinion with 15 teeth. Power is transmitted further through gears $\frac{25}{25} \times \frac{28}{22}$, and change gears $\frac{E}{F}$ to a drum with a helical slot. The pin actuating the rear carriage enters this slot. The 12 change gears $\frac{E}{F}$ provide for 12 different cross feeds to each set-up feed of the longitudinal (front) carriage. Cross feeds range from 0.016 to 2.37 mm per spindle revolution.

Rapid traverse movements (rapid advance to the work and withdrawal of the carriages) are powered from a separate 1-kW reversible motor, linked to the feed gear train through the two-direction overrunning clutch C_0.

The semiautomatic working cycle of the machine consists of rapid advance of the front and rear carriages, change-over to working feed, rapid return of the carriages to the initial positions and stopping of the lathe. The cycle

The model 1712 semiautomatic tracer-controlled lathe* is shown in Fig. 53. It has a tracer-controlled slide *1* and one or two cross slides *2* which machine the parts of the work that cannot be turned to a template (cutting narrow or deep grooves, facing reverse shoulders, etc.). The possibility of tracing to a flat template or master, and the simplicity with which a dull tool can be changed enable the time required to change over to a new job to be considerably reduced. Machining time can also be reduced in comparison to multiple-tool machining (without a tracing slide) due to the higher cutting speeds that can be applied and the rapid traverse of the tool at the sections of the work which do not require machining.

Automatic turning of the work in several passes with rational distribution of the machining allowance among the passes enables blanks with different allowances at different parts to be turned efficiently in a single lathe, i.e., without using several lathes with different setups. Thus, in turning work of complex shape, a tracer-controlled multiple-tool semiautomatic is frequently more productive than ordinary multiple-tool lathes.

2-17. Single-Purpose Lathes

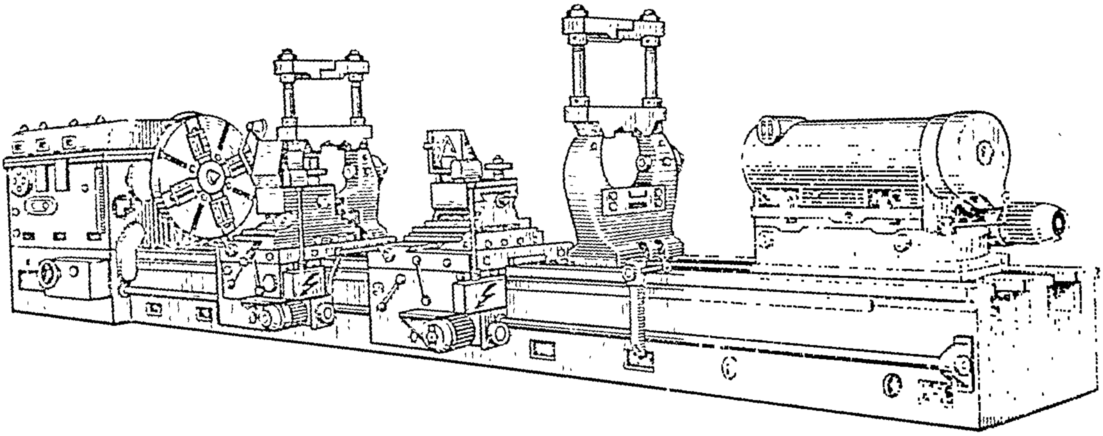
In addition to the machines that have been considered, the lathe group includes various single-purpose lathes designed for turning work in large lots in various fields of industry.

Special roll-turning lathes (Fig 54) find application for the rough and finish turning of rolls for rolling mills in plants where metal rolling equipment is manufactured and operated These lathes possess high rigidity which, in conjunction with the amply powered drive, enables carbide-tipped tools to be employed to their full capacity Lathes of this type are usually equipped with several carriages and special steady rests that allow the mating roll to be set up when the pass grooves are being turned with the aid of an electric tracing device.

Special lathes are used in the steel-making industry for roughing straight and tapered ingots of round and square cross section, for cutting off the ingot head and for slicing tire ingots into billets for the wheels and tires of railway rolling stock

Plants manufacturing Diesel engine locomotives and freight cars, as well as railway repair shops use wheel lathes (Fig. 55) and axle lathes intended for turning the tires, rims and axle journals of the wheel sets of railway vehicles.

*The hydraulic system diagram of the model 1712 lathe is similar to that of the model MP105 lathe (see Fig 289).



III Fig. 54. Roll-turning lathe, model 1825

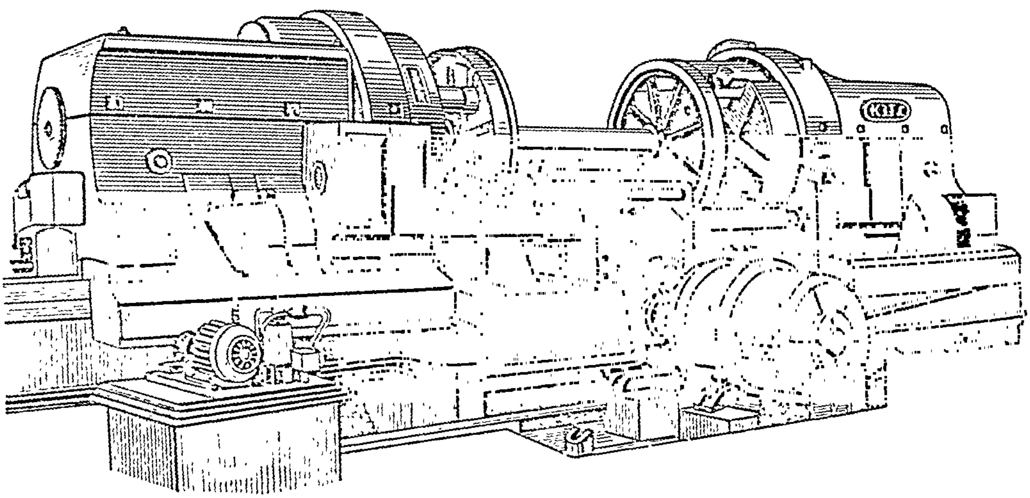


Fig. 55. Wheel lathe, model 1836

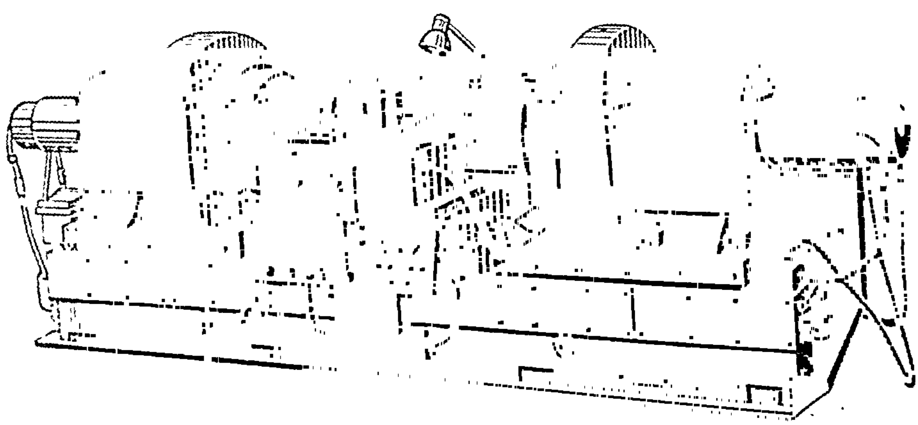


Fig. 56. Semiautomatic crankshaft lathe, model 1A857

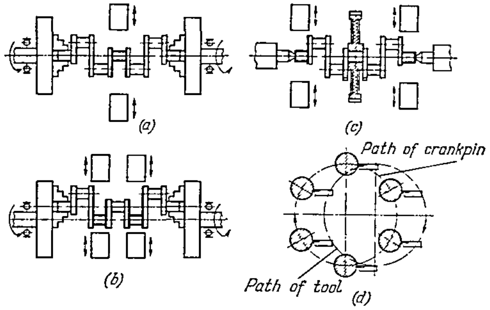


Fig 57. Operations in turning a crankshaft

Plants manufacturing internal-combustion engines employ special-purpose semiautomatic crankshaft and camshaft lathes.

The main journals of a crankshaft are turned, and the adjacent cheeks and the ends of the crankshaft can be faced in either of two types of lathes: with two-sided and with centre drives. In lathes with a two-sided drive (Fig. 56) the tailstock spindle is power driven and rotates synchronously with that of the headstock. The central main journals of crankshafts can be turned in such a machine (Fig. 57*a*), and the adjacent cheeks can be faced. The crankpins can also be turned and their adjacent cheeks faced if the crankshaft is set up and clamped so that the axis of coaxial crankpins coincides with the spindle axis (Fig. 57*b*).

The main journals at the ends of the shaft are turned in lathes with a centre drive (Fig. 58). In this case the shaft, mounted between centres, passes through a gear clamped on the previously roughed central journal (Fig. 57*c*).

Lathes are available that simultaneously turn all the crankpins on a crankshaft. Here the shaft is set up as shown in Fig. 57*a* and the carriages in which the tools are clamped travel in a circle (synchronously with crankshaft rotation) whose radius is equal to the throw of the crankshaft (Fig. 57*d*).

Heavy crankshafts are machined in lathes of the type illustrated in Fig. 59, in which the blank is clamped stationary in steady rests *2*. The

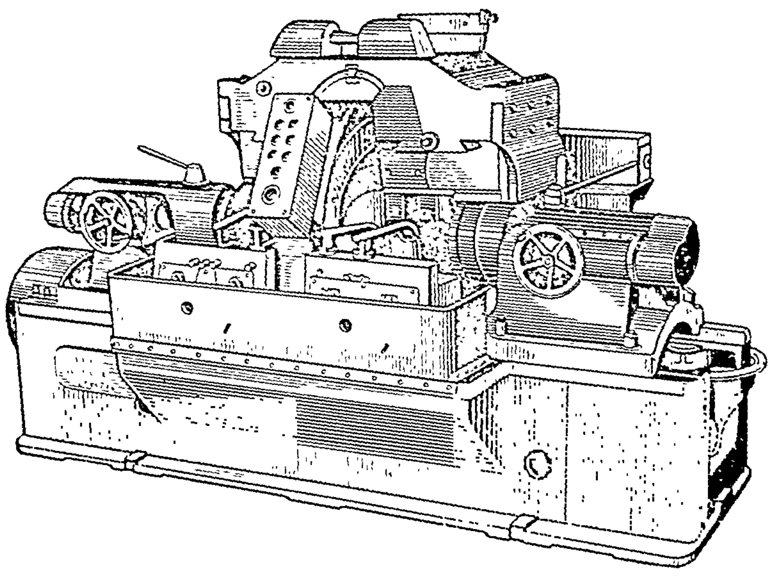


Fig. 58. Semiautomatic crankshaft lathe, model 1A84

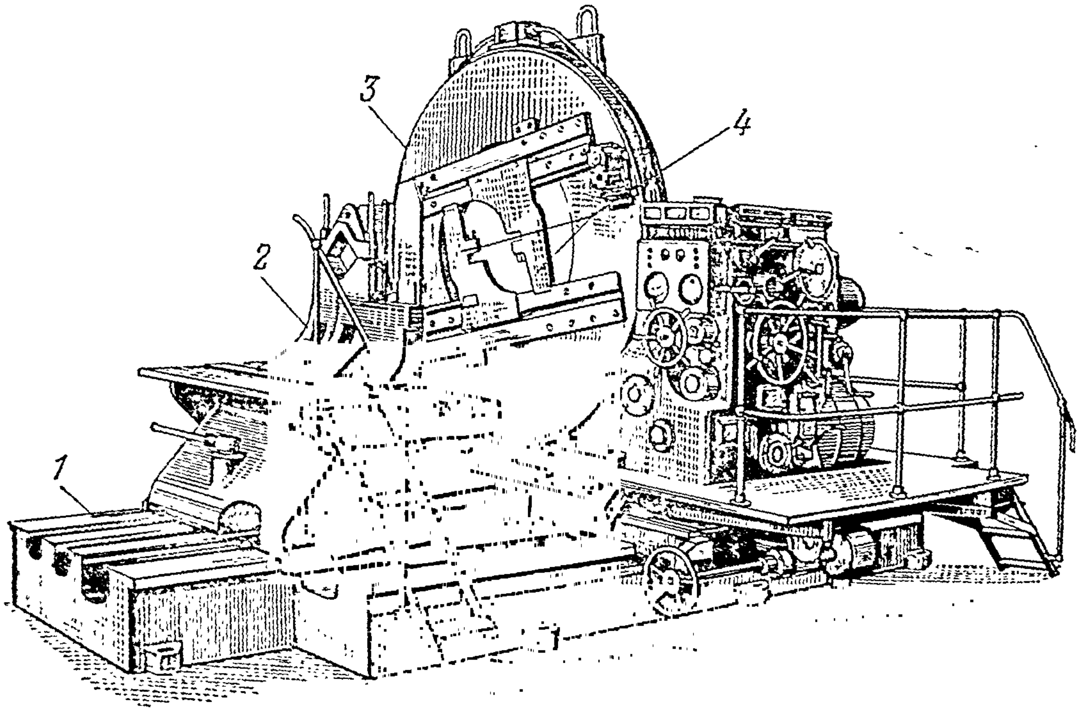


Fig. 59. Lathe with rotating tools for turning the journals and crankpins of a crankshaft consecutively

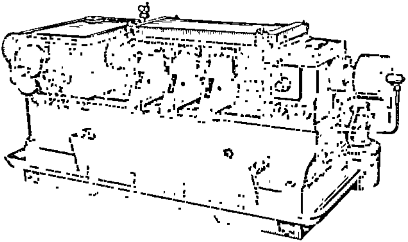


Fig. 60. Semiautomatic camshaft lathe, model 1893

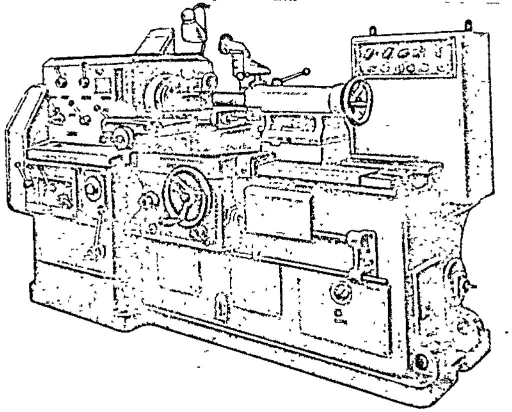


Fig 61 Relieving lathe, model 1811

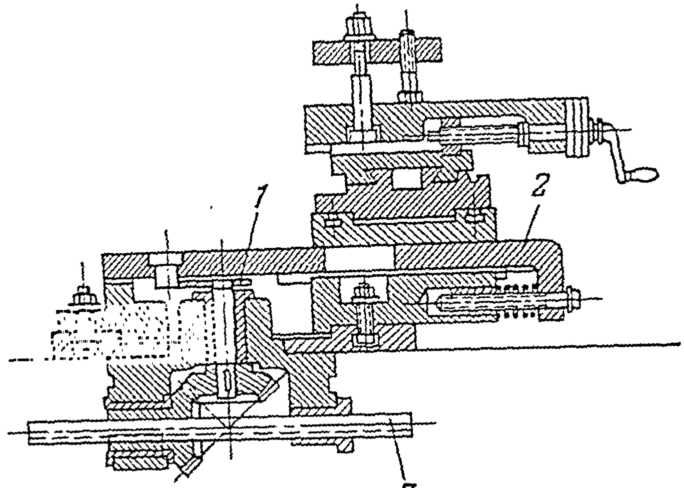


Fig. 62. Carriage of a relieving lathe

main journals and crankpins are consecutively turned by two tools clamped in slides *4* on faceplate *3*. Slides *4* have radial feed to feed the tools into the cut while the faceplate has longitudinal feed along the ways of bed *1*. The faceplate can also be traversed crosswise to align its centre with the centre of the journal being turned on the crankshaft.

Semiautomatic multiple-tool lathes with two-sided or centre drives are used to turn engine camshafts. The lathes with a two-sided drive (Fig. 60) are used to turn the journals and face the sides of the cams in the middle part of the camshaft, and also to simultaneously turn the contours of all the cams. The lathes with a centre drive are employed to turn the journals and face the cams at the ends of the camshaft.

Relieving lathes (Fig. 61) are used in the tool industry to relieve or back off the teeth of various types of milling cutters, hobs and other tools (see Fig. 37, Vol. 2). Relieving lathes differ from the ordinary general-purpose models in that a reciprocating motion is imparted to the toolpost slide *2* (Fig. 62). This motion consists of a slow advance forward, during which the tool backs off the tooth of the cutter, and a rapid return to the initial position to start the relieving movement for the next tooth.

Reciprocation is effected by cam *1* which is driven by shaft *3*. The latter is linked to the main drive which rotates the work. The kinematics of relieving lathes is taken up in more detail in Vol. 2, Part Three, Sec. 5-2.

CHAPTER 3

TURRET LATHES AND VERTICAL BORING MILLS

3-1. Purpose and Field of Application of Horizontal Turret Lathes

Horizontal turret lathes are designed for machining work of complex shape on a lot-production basis. External surfaces are machined by single-point tools of various types; central holes, by boring tools, drills, taps, etc.

The main distinguishing feature of a turret lathe is the provision of a *longitudinal slide* or *saddle* carrying a multiple-station *turret* in which various kinds of tools are clamped.

By swivelling (indexing) the turret, the tools, preset to size, are consecutively brought into the cutting position and fed to the work. This considerably reduces handling time in the machining operation.

TABLE 8

Model	Bar capacity (diameter of work clamped in chuck), mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx	Remarks
1314	10	Up to 5,000	1.5	350	Vertical turret axis
1H318	18	100 to 4,000	2 6/3	1,000	Ditto, with programmed cutting speeds and feeds
1H325	25	Up to 3,500	3 or 4	1,200	
1B340	40 (400)	60 to 2,000	7.5	2,400	Ditto
1B365	65 or 80 (500)	34 to 1,500	13	3,900	Ditto
1П371	100 or 125 (630)	20 to 893	30	6,300	Ditto, with preselective controls
1П381	160 or 200 (800)	14 to 630	30 to 40	8,500	Ditto
1Г325	25	80 to 3,150	2.6/3	1,300	Horizontal turret axis
1A341	40	60 to 2,000	5.5	2,200	Ditto
1416	— (160)	60 to 2,000	5.5	3,000	Semiautomatic chucking type
1425	— (250)	50 to 1,250	7.5	4,200	Ditto

In most cases, in addition to the turret, these lathes have a cross slide with a square turret in which single-point tools are clamped for turning external surfaces on the work.

The main dimensions of a horizontal turret lathe are the bar capacity and the maximum diameter machined over the bed.

Brief specifications for Soviet models of horizontal turret lathes are given in Table 8.

3-2. Working and Auxiliary Motions in Horizontal Turret Lathes

The primary cutting motion (v, Fig. 63) of a turret lathe is the rotation of the spindle carrying the work. The feed motions are the longitudinal travel s_1 of the turret and the cross travel s_2 of the cross slide carrying the cutting tools. In some cases, cross feed is obtained by slow rotation of the turret (with a horizontal axis) or by crosswise motion of the turret.

Auxiliary motions of a turret lathe are:

(a) swivelling (indexing) of the turret for bringing the tools consecutively into the cutting position;

(b) feeding out and clamping the bar stock;

(c) rapid approach and withdrawal of the turret, cross slide, etc.

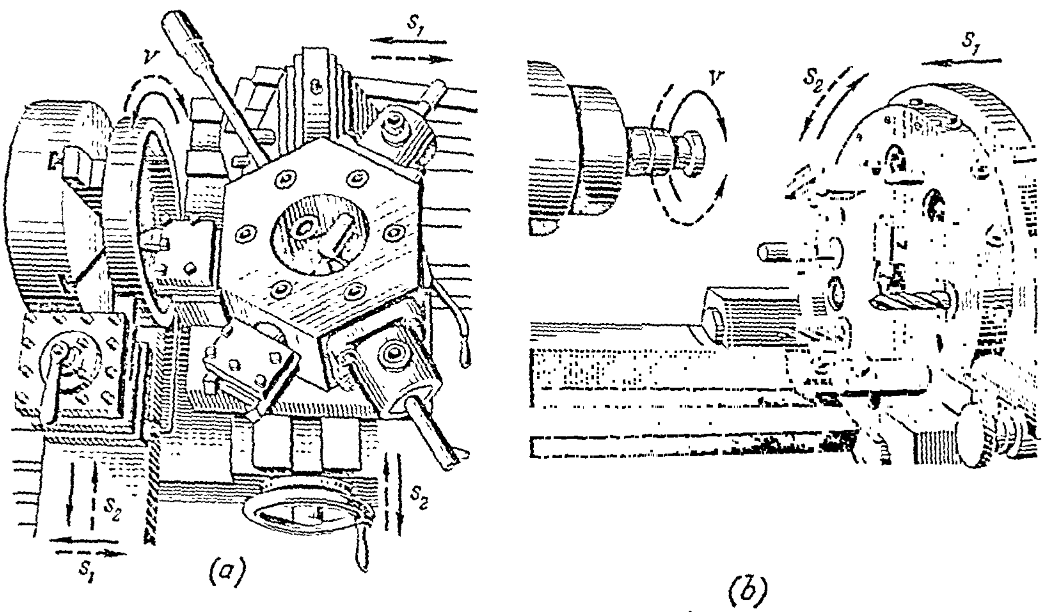


Fig. 63. Working motions in horizontal turret lathes

3-3. Construction Arrangement and Principal Units of Horizontal Turret Lathes

Depending upon the arrangement of the turret axis of rotation (Table 8), *three designs of turret lathes are available: with a horizontal, vertical or* inclined axis of the turret.

Most of the small-size turret lathes are of the ram, or capstan, type in which a slide or ram carrying the turret moves toward or away from the work in a saddle clamped to the lathe bed. The saddle can be adjusted along the bed ways.

In the heavier turret lathes the turret is mounted directly on the saddle which, in the same way as the cross slide, travels along the bed ways.

As to the type of blank or stock they handle, turret lathes are classified as *bar* and *chucking models.*

In the bar machines the work is turned from bar stock of the required cross section which passes through the hole in the spindle and is clamped in a *collet chuck* (or chuck with interchangeable jaws). For this purpose the lathe is equipped with a mechanically, pneumatically or hydraulically operated collet chuck and bar feed units.

In the chucking machines a separate blank (a casting or forging) is clamped in an independent jaw chuck mounted on the spindle nose.

Up-to-date models of horizontal turret lathes have preselected (previously selected) spindle speeds and tool feeds, or speed and feed changing is automatically controlled.

Heavy turret lathes, whose operation involves large machining times, have control systems in which the spindle speed and rates of feed for the next operation element can be selected in the course of the present operation element. After indexing the turret (by hand or power), the shifting of a single lever engages the preselected speed and feed. This is accomplished in most modern lathes by friction or jaw clutches, built into the speed and feed gearboxes and controlled by hydraulic cylinders In certain cases, sliding cluster gears are directly shifted by hydraulic cylinders.

Small and medium-size turret lathes usually perform operations with a small machining time and have automatic turret indexing Here, the spindle speeds and rates of feed for each turret position are set up beforehand and they change consecutively in the course of the operating cycle depending upon the position to which the turret is indexed. This is provided by electromagnetic friction clutches built into the speed and feed gearboxes. The clutches are engaged by rotary automatic control units linked to the turret.

Handling time, lost in changing spindle speeds and rates of feed each time the turret is indexed, is substantially reduced when preselection or automatic controls are employed. This is of special importance in lot production.

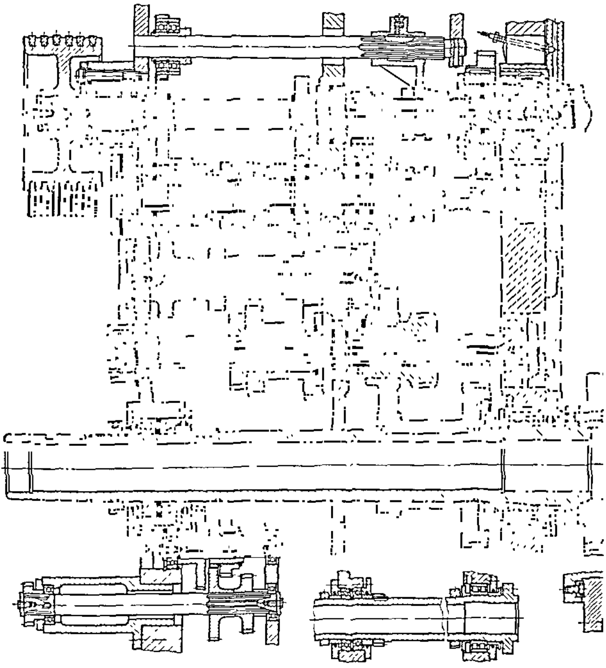


Fig. 65. Development through the shafts of the headstock on the model 1П365 turret lathe

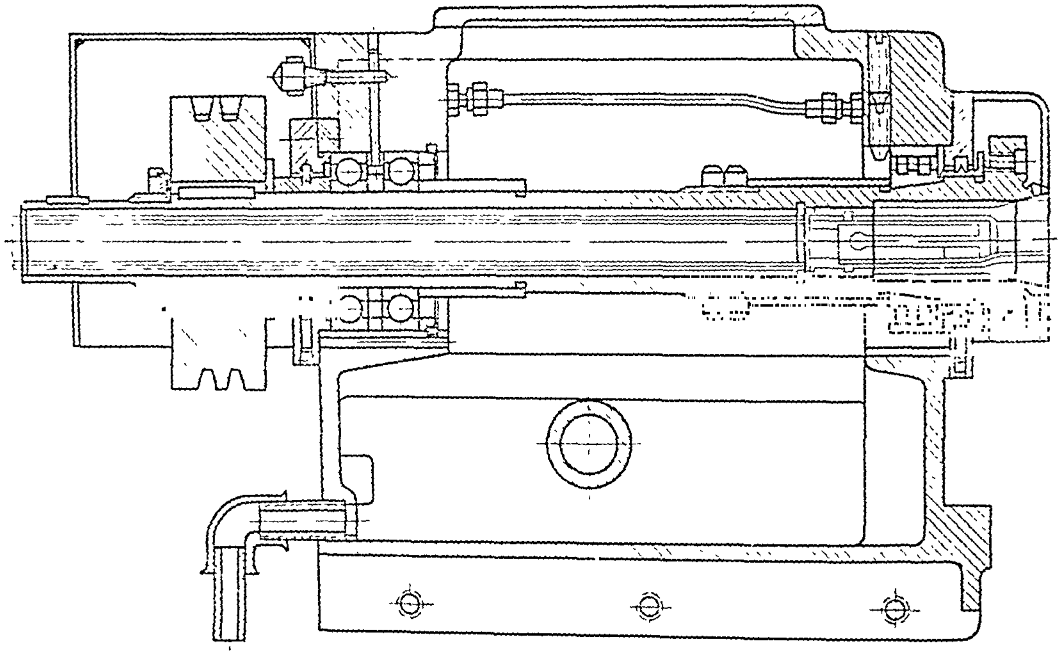


Fig. 66. Headstock of the model 1П326 turret lathe

The *feed gearbox* of a turret lathe is simpler than the unit of this name in an engine lathe because it requires a narrower range and fewer steps of feed. Moreover, it does not have an arrangement for cutting threads with a lead screw.

The feed gearbox of a heavy turret lathe may have a device enabling the feeds to be changed without stopping the lathe (Fig. 68). Before each speed change, the hydraulic control system disengages clutch *1* linking the feed and speed gearboxes and engages clutch *2* mounted freely on its shaft and having a rocking motion obtained from an eccentric cam *3* mounted on the rapid traverse shaft. Thus, the feed gearbox shafts turn back and forth slowly, thereby facilitating the shifting of the sliding cluster gears while the lathe is in operation.

In small and medium-size turret lathes, feeds are changed during operation by means of electromagnetic friction clutches which can be engaged in various combinations (Fig. 69).

The *aprons* of the cross slide and turret saddle serve to provide hand and power traverse of these units in the cross and longitudinal directions. They have mechanisms for stopping the saddle and cross slide in the required position as determined by preset stops, and rapid traverse mechanisms. The rapid traverse mechanism (only for rapid withdrawal of the turret

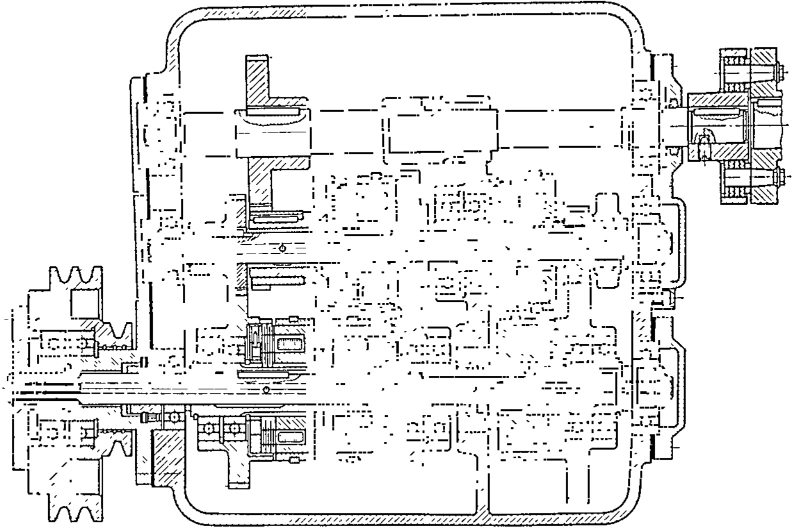


Fig. 67. Reducing gear of the model 1П326 turret lathe

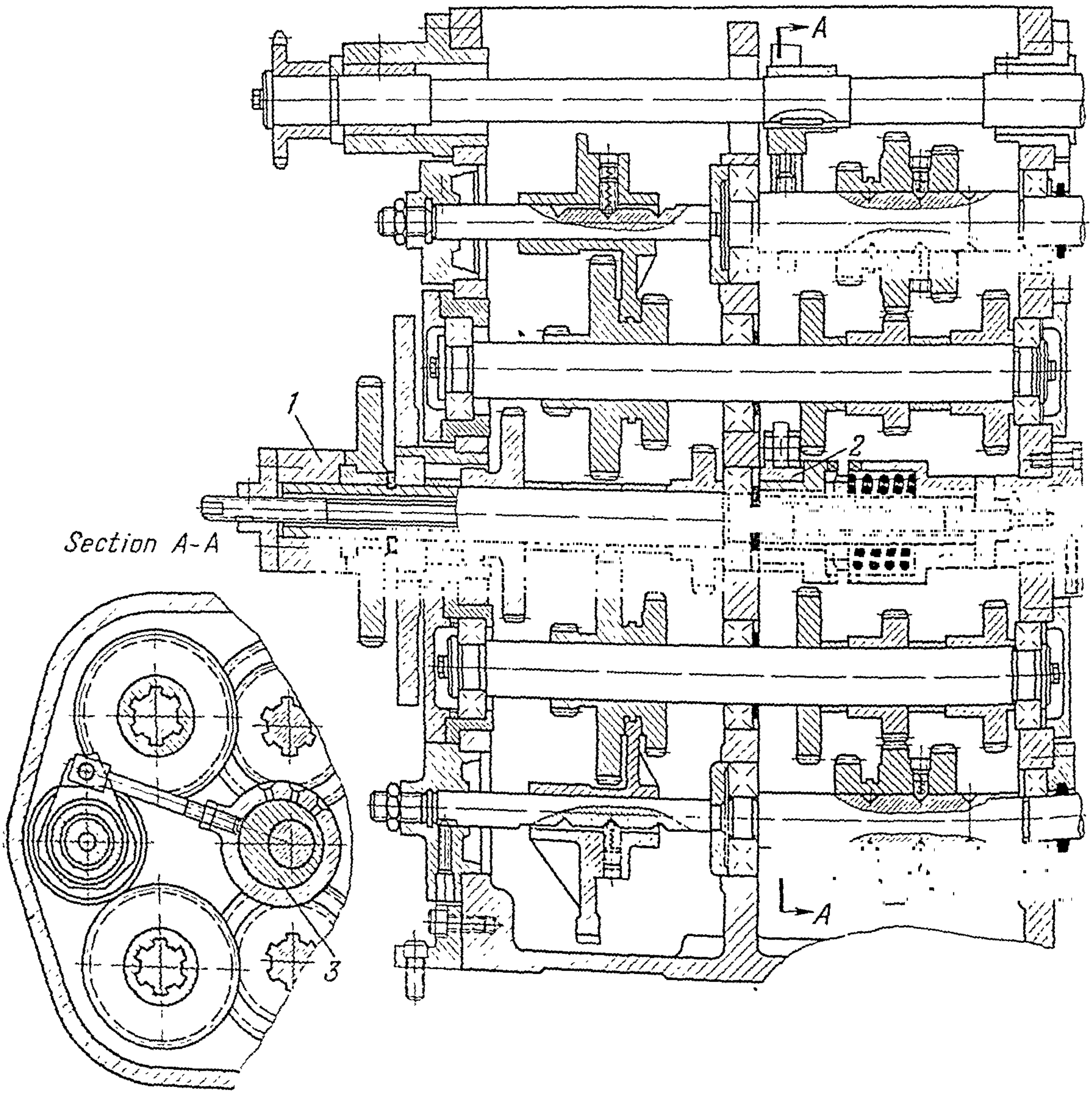


Fig. 68. Feed gearbox of the model 1П365 turret lathe

saddle or slide in small and medium models) is powered from a separate motor through the rapid traverse shaft.

The *cross slide carriage* of a turret lathe may be of either the "reach-over" (Fig. 70) or "side-hung" (Fig. 71) type. The construction of the reach-over, or bridge, type of cross slide carriage is more rigid and allows a second toolholder to be mounted at the rear.

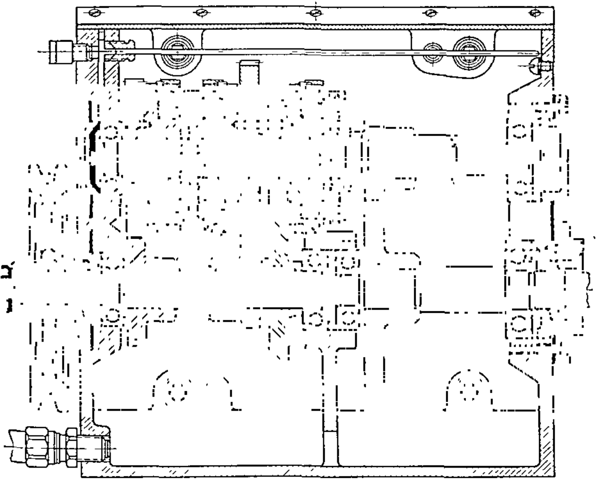


Fig. 69. Feed gearbox of the model 1П326 turret lathe

The front toolpost is of the square turret type with four indexed positions. The rear toolholder has only a single position and may hold several tools. A drawback of the reach-over cross slide (in comparison with the side-hung type) is that the diameter that can be machined is limited to a greater extent because the work must be accommodated over the cross slide.

The side-hung type of cross slide enables work of considerably larger diameter to be machined on a turret lathe of the same size. A disadvantage of this type of cross slide is the lower rigidity which reduces the number of tools that can be used simultaneously.

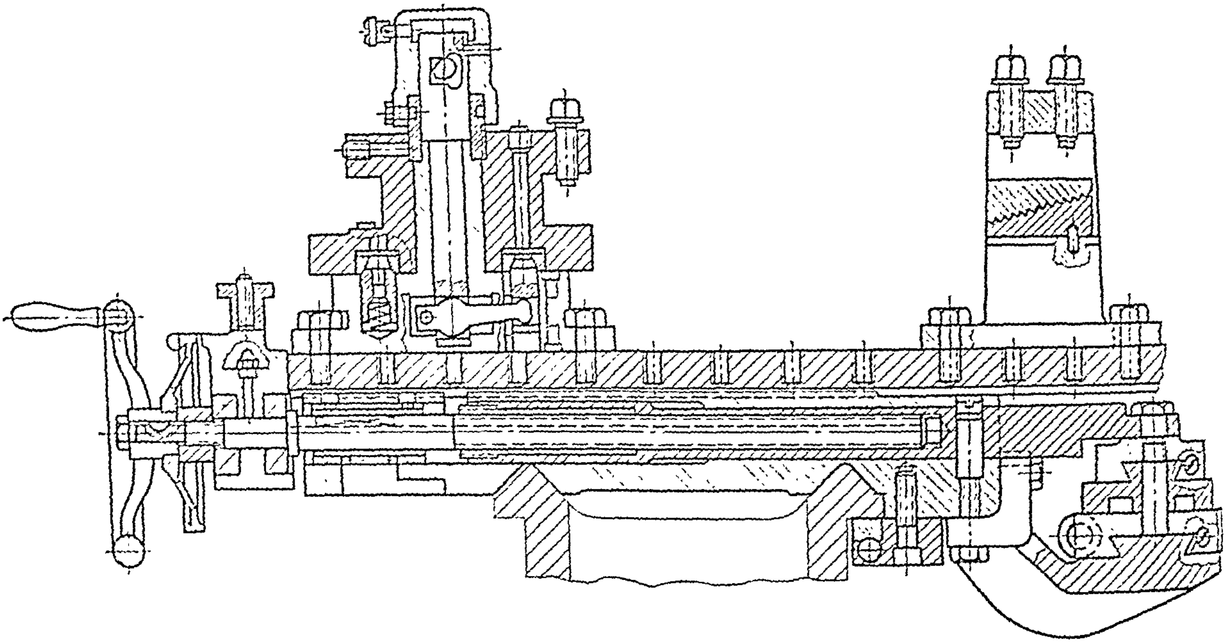


Fig. 70. The "reach-over" type of cross slide carriage

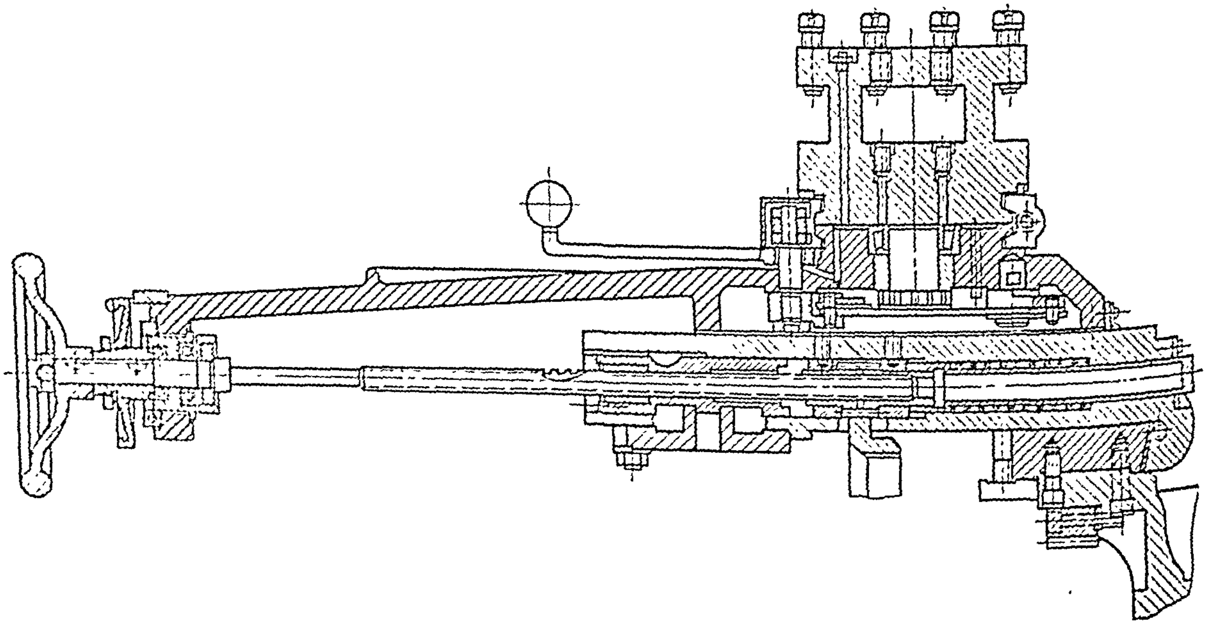


Fig. 71. The "side-hung" type of cross slide carriage

The *saddle 1* in small and medium-size turret lathes with a vertical axis of turret rotation (Fig. 72) is mounted on the bed and the turret slide or ram *2* moves back and forth in the guides of the saddle from a rack-and-pinion drive and carries the hexagon (or, less frequently, cylindrical) turret *3*. The cutting tools are clamped in the holes of the turret in toolholders and adapters of various types. Various attachments carrying the cutting tools can be mounted on the faces of the turret. A locking pin ensures that the turret holes are in strict alignment with the spindle axis after each indexing of the turret. Tapered locking pin *11* enters one of the six bushings fitted in the base of the turret.

The turret clamp, whose main element is the clamping ring, or yoke, *4*, serves to clamp the turret rigidly following each indexing and to relieve the locking pin of shearing stress due to the cutting force and the consequent torque developed in the turret. In the clamped position the base of the turret bears tightly against the mating surface on the saddle.

The turret indexes automatically when the ram is retracted. During retraction of the ram one of the indexing pins *9* runs up against the lever of stop *10*, mounted in saddle *1* and the turret is indexed through 60°. Before the turret begins to index, lever *12* runs up on stop *13* and retracts locking pin *11*. At the same time dog *14* engages cam *15*, releasing the turret clamp. At the beginning of the forward movement of the ram, the turret is clamped by the interaction of dog *14* and the stop.

Stop spool *6* with stop screws *5*, used for presetting the length of travel of the turret ram for each turret position, indexes synchronously with the turret. When the ram reaches the end of its travel for a certain position of the turret the corresponding stop screw *5* runs up against stop pin *7* mounted in saddle *1*. By means of shaft *8*, pin *7* actuates the mechanism located in the apron of the turret saddle for disengaging the working feed. This mechanism disconnects the feed gear train by means of a claw clutch, and ram *2* stops in the preset position. Automatic feed disengagement is accurate to within 0.1 or 0.2 mm.

In the small-size lathes (models 1П318 and 1П326, Fig. 73) the turret slide travels directly along the bed ways. This excludes the need for additional ways and increases the bearing surface of the slide.

The stops controlling turret indexing, locking pin retraction and turret clamping, as well as the pin of the stop for disengaging the working feed are arranged in a special housing mounted on the bed. The turret slide apron of these machines is stationary.

In the heavy turret lathes, the turret saddle *1* (Fig. 74), together with the apron fastened to it, travels directly along the bed ways by means of a rack-and-pinion drive, thereby providing for a considerable length of travel.

Turret *3* is not indexed automatically as in the smaller models. Locking pin *4* is retracted, and clamping ring *2* is released and closed by hand using

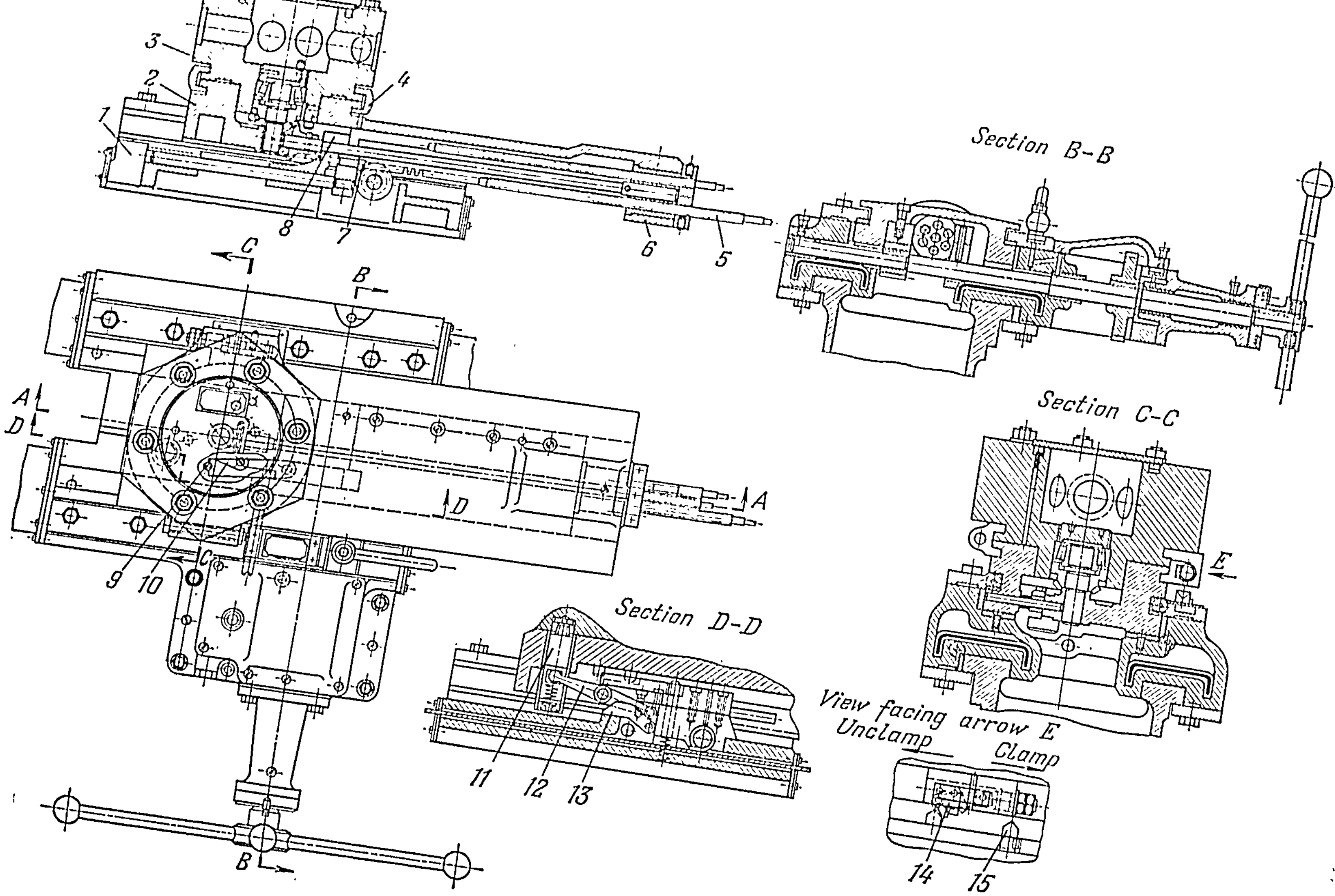


Fig. 72. Ram-type turret of the model 1325 turret lathe

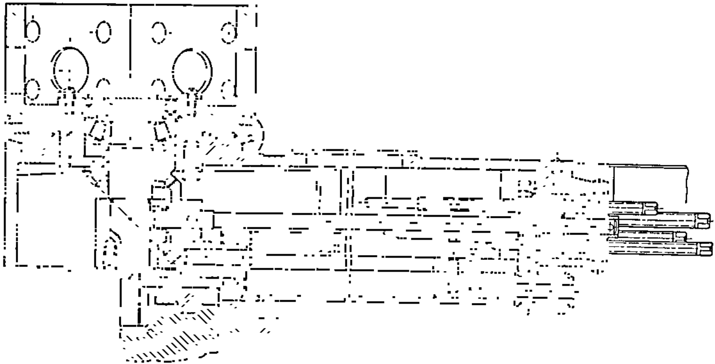


Fig. 73. Turret saddle unit of the model 1П326 turret lathe

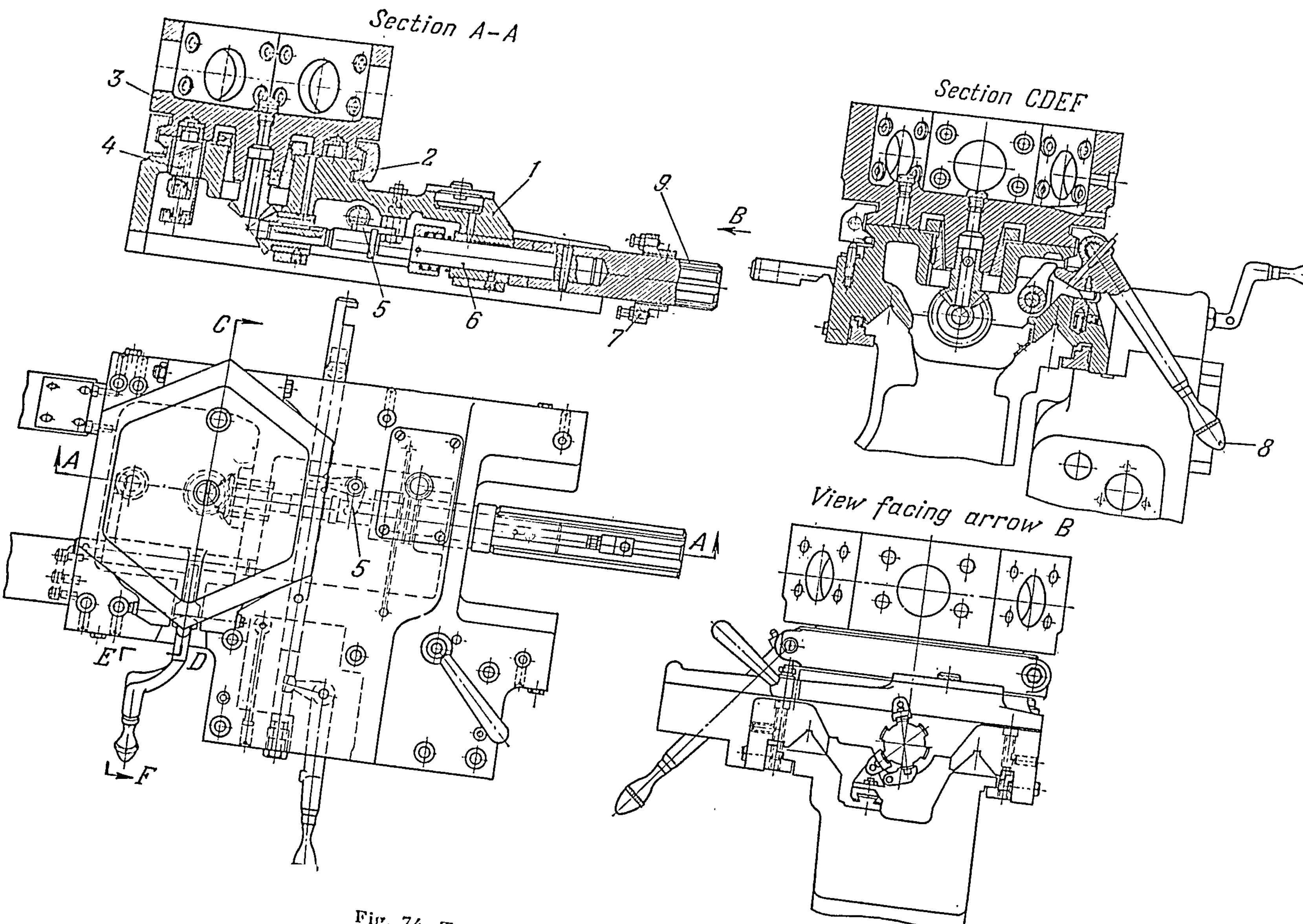


Fig. 74. Turret saddle unit

lever *8*. Stop spool *9* indexes synchronously with the turret to which it is linked through bevel gearing. The spool carries adjustable stops *7* by means of which the length of travel of the turret is set up for each position. In the forward feed of the saddle, corresponding stop *7* runs up against a stationary stop on the bed. At this, stop spool *9* is stopped but the saddle continues to travel forward. Then the shoulder of shaft *6*, which is fitted into the stop spool, turns lever *5*. The latter, through shaft *6*, trips the mechanism for disengaging the working feed, located in the turret saddle apron. As a result, the *power feed gear train is disengaged and the saddle stops in the required* position.

Some designs of turret lathes incorporate a Geneva mechanism or a hydraulic cylinder for indexing the turret.

The turret saddle of lathes with a horizontal axis of turret rotation (Fig. 75) is traversed directly along the bed ways by means of a rack-and-pinion drive. The apron of the saddle is stationary. The turret *1* has 12 to 16 tool holes into which tools or attachments with tools are mounted. As each tool hole is indexed to its uppermost position it comes into alignment with the spindle axis.

Locking pin *2* serves to positively position the axis of each tool hole accurately in line with the spindle axis. The locking mechanism is controlled by hand from lever *15*.

The following three types of turret rotation are available:

(1) Rapid manual indexing is accomplished by turning handwheel *12*. The latter is mounted on shaft *10* together with gear *16* which meshes with the gear teeth on the turret unit. Before indexing in this manner, friction clutch *11*, linking worm wheel *9* to shaft *10*, is disengaged by means of knob *13*.

(2) Slow manual rotation to obtain cross feed is effected by turning handwheel *7*. The gear train is through shaft *5*, worm *4*, worm wheel *9*, clutch *11* and further as in the first case.

(3) Slow power cross feed is effected by shaft *3* which is driven by the mechanism of the saddle apron. The gear train includes bevel gears *8*, which serve to reverse the cross feed when claw clutch *6* is shifted by lever *14*, and the other elements indicated in the second case.

The *bar feed and clamping mechanism* is a unit of all bar type turret lathes. In small-size lathes this mechanism is mounted on the left end of the bed (Fig. 76).

The bar stock is clamped in the following manner. Shaft *2*, driven from a separate motor, carries drum *1* with a curvilinear groove by means of which the roller of clamping lever *3* is actuated. Upon rotation of drum *1*, lever *3* turns counterclockwise, shifting sleeve *8*, mounted on the rear end of the spindle, toward the left. The internal taper of sleeve *8* forces rollers *9* between washer *7* and cage *10*. Since washer *7* is fixed axially, cage *10*, compensator *11*, bushing *12* and nut *13* are shifted to the left. Nut *13* is

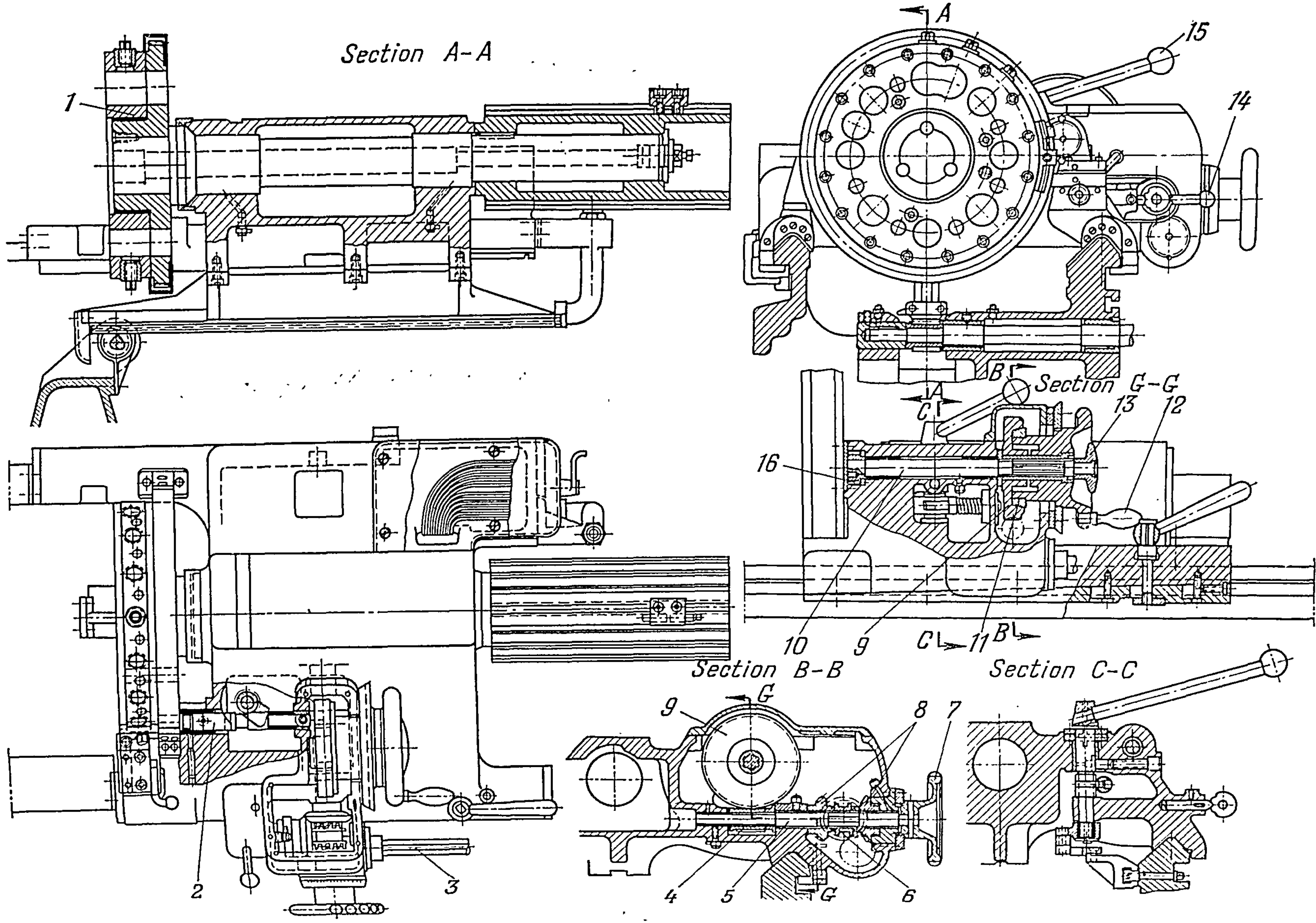


Fig. 75. Turret saddle unit of a turret lathe with a horizontal axis of turret rotation

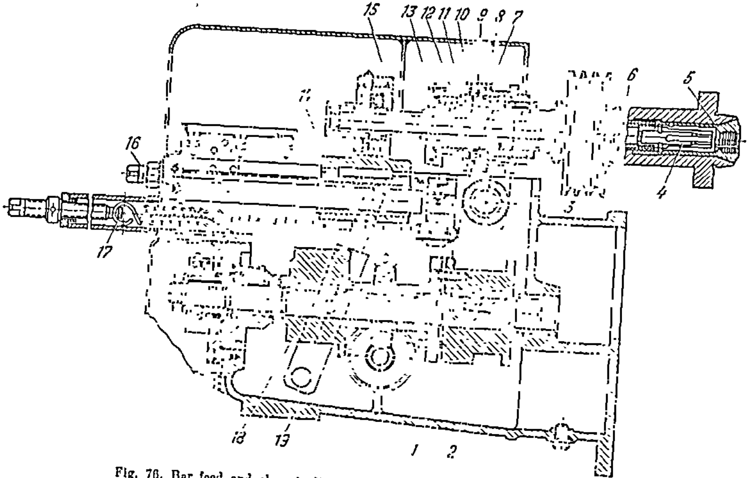


Fig. 76. Bar feed and clamping mechanism of the model 1П326 turret lathe

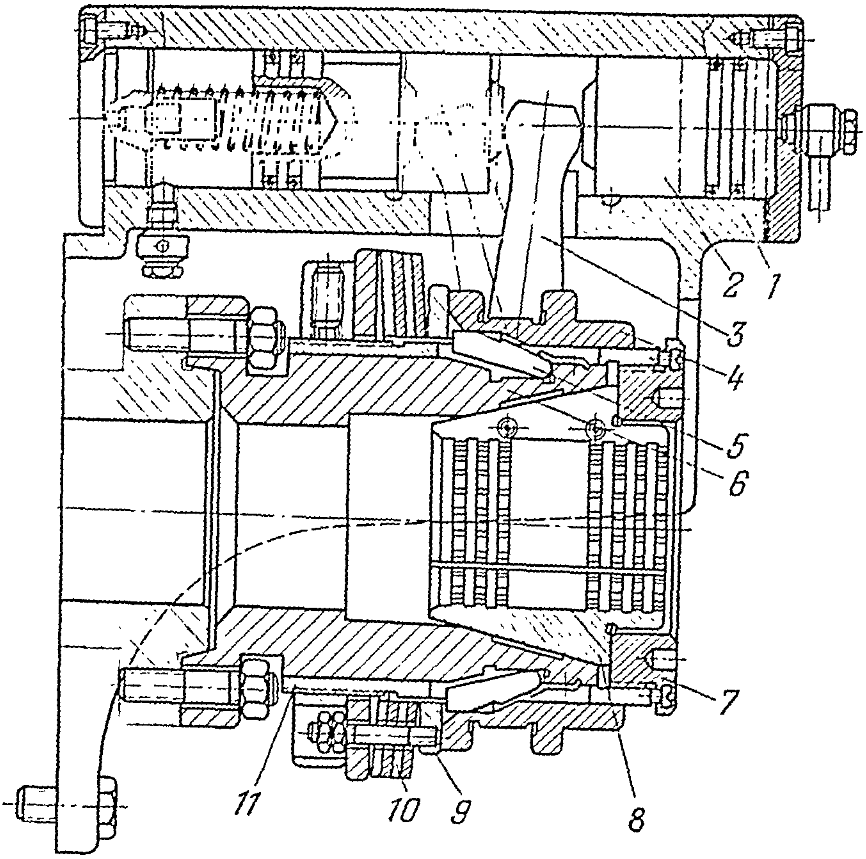


Fig. 77. Bar clamping mechanism of the model 1365 turret lathe

secured on collet tube 6 which passes through the hole in the spindle. Interchangeable spring collet 5 is screwed on the front end of collet tube 6 and its conical surface fits a tapered hole in the spindle nose. When tube 6 shifts to the left the collet is drawn into the tapered hole so that it springs and clamps the bar stock.

Because of its elastic properties the collet opens and releases the bar stock when sleeve 8 is shifted to the right and parts 5, 6, 13, 12, 11, 10 and 9 return to the initial position.

The stock is fed out for a new workpiece as follows. Bar feed drum 18 is mounted on the same shaft 2 and has a curvilinear groove which actuates the roller of bar feed lever 19. Upon rotation of the drum, lever 19 turns clockwise and shifts feeding slide 14, in which feeding tube 15 is secured, to the right. Feeding tube 15 is arranged inside collet tube 6. An interchangeable feeding finger 4 is mounted at the right end of the feeding tube. This finger grips the stock with a certain force because its jaws were compressed before

heat treatment. This force should be sufficient to feed the bar out when the collet is released. The feeding finger and tube are moved back to the left by the action of spring *17* (as permitted by the shape of the groove on drum *18*). At this time the bar is firmly clamped by the spring collet so that the feeding finger returns to its initial position, sliding over the bar. Screw *16* is used to set up the stroke of the feeding finger.

The whole bar feed and clamping cycle takes place during one revolution of shaft *2*. The cycle includes return of the feeding finger, unclamping the bar, feeding out the bar and clamping it again.

The mechanism employed for clamping bar stock in a heavy turret lathe is illustrated in Fig. 77.

The bar is clamped in the following way. Oil under pressure enters the right end of cylinder *1*, shifting piston *2* and the top of shifting fork *3* to the left. Acting through sleeve *4*, chuck levers *5*, washer *9*, compensating springs *10* and other intermediate components, shifting fork *3* moves sleeve *11* to the left. Through nut *7*, sleeve *11* forces separate interchangeable jaws *8*, held apart by springs, into the tapered hole of part *6*. This compresses the jaws and clamps the bar. The bar is released by admitting oil to the left end of the hydraulic cylinder.

In heavy turret lathes the bar feeding and clamping mechanism is designed as a separate unit arranged at the left end of the speed gearbox. In Soviet models this mechanism has a hydraulic drive. In its operation, the bar is first gripped by two levers actuated by two cylinders and then the feed cylinder advances the bar

3-4. Turret Lathe, Model 1365

The model 1365 turret lathe is intended for turning work from bar stock with carbide-tipped or high-speed steel tools. The bar capacity is 80 mm. The lathe has a hexagon turret with a vertical axis of rotation. One modification of model 1365 is model 1П365 designed for chucking operations. The maximum diameter of workpiece accommodated over the bed is 500 mm. The gearing diagram of model 1365 is shown in Fig. 78.

The speed gearbox imparts 12 forward and 12 reverse speeds to the spindle in a range from 34 to 1,500 rpm. The spindle is reversed by twin friction clutch C_1.

Forward rotation of the spindle is obtained through gears $\frac{42}{48}$ and with clutch C_1 shifted to the right; reverse rotation—through gears $\frac{40}{45}$ and intermediate gear $35T$ with clutch C_1 shifted to the left.

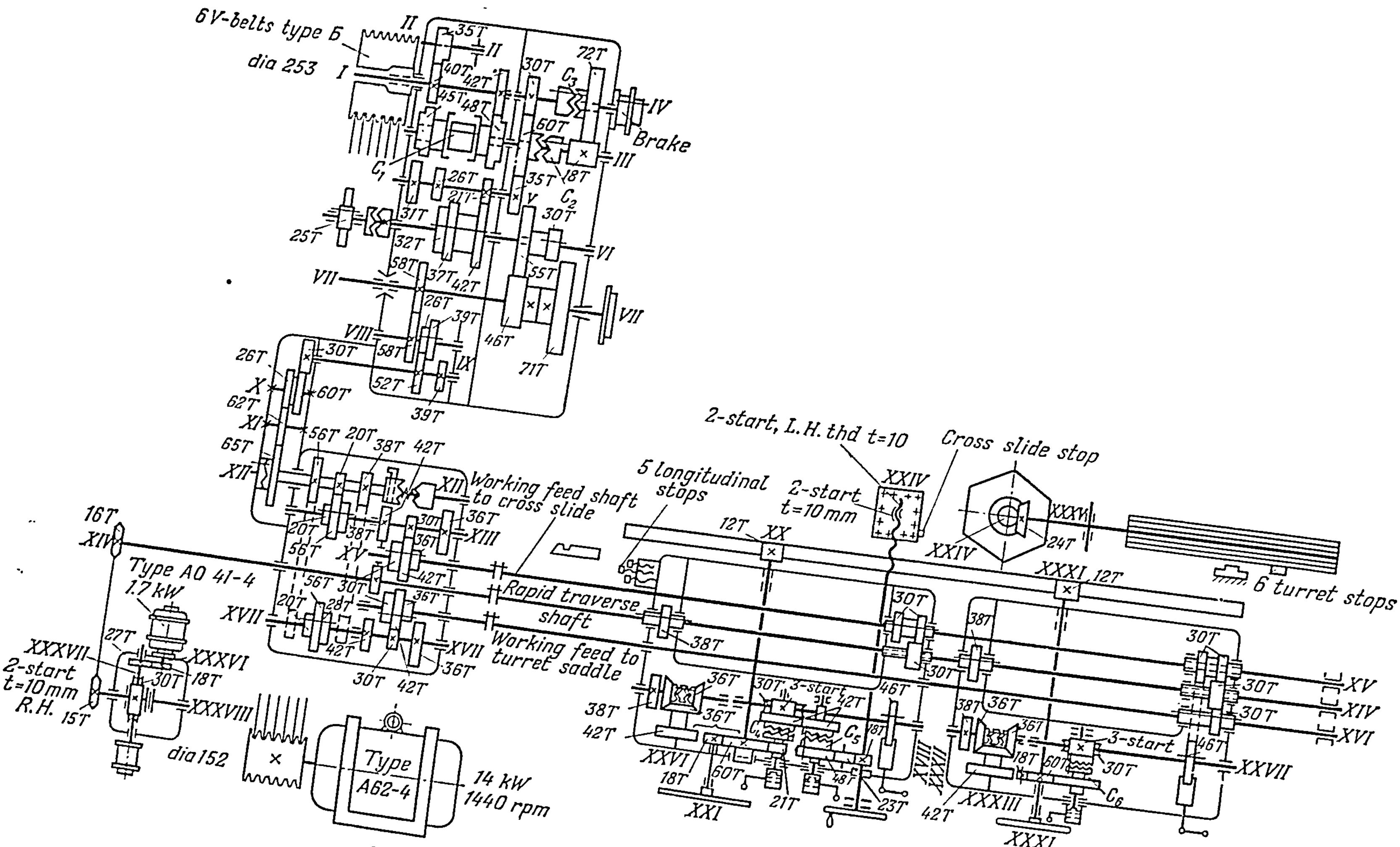


Fig. 78. Gearing diagram of the model 1365 turret lathe

In forward rotation of the spindle the six upper speeds of the range are obtained through the gear train: shaft *I*, gears $\frac{42}{48}$, shaft *III*, gears $\frac{60}{35}$ (with clutch C_2 engaged and clutch C_3 disengaged), shaft *V*, sliding triple cluster gear $\frac{21}{42}$ or $\frac{26}{37}$ or $\frac{31}{32}$, shaft *VI*, sliding double cluster gear $\frac{55}{46}$ or $\frac{30}{71}$ and to the spindle.

The six lower speeds of the range are obtained through the gear train: shaft *I*, gears $\frac{42}{48}$, shaft *III*, gears $\frac{18}{72}$ (with clutch C_3 engaged and clutch C_2 disengaged), shaft *IV*, gears $\frac{30}{60} \times \frac{60}{35}$, shaft *V*, sliding triple cluster gear $\frac{21}{42}$ or $\frac{26}{37}$ or $\frac{31}{32}$, shaft *VI*, sliding double cluster gear $\frac{55}{46}$ or $\frac{30}{71}$ and to the spindle.

The cross slide carriage and the turret saddle each have 18 longitudinal feeds obtained from the spindle through the main gearbox, feed gearbox, feed rods *XVI* and *XV*, aprons of the carriage and saddle, and the rack-and-pinion drive.

The feed gear train commences with the constant gearing $\frac{58}{58} = 1$ and the double cluster gear $\frac{26}{52} = \frac{1}{2}$ or $\frac{39}{39} = 1$, due to which the number and rates of feed are doubled. Next along the train are the main gearbox with a constant gearing ratio $i = \frac{30}{60} \times \frac{26}{62} \times \frac{62}{65} = 0.2$ and the feed gearbox providing nine engagements between shaft *XII* and shaft *XV* by means of the two triple cluster gears: $\frac{56}{20}$ or $\frac{20}{56}$ or $\frac{38}{38}$, and $\frac{42}{30}$ or $\frac{30}{42}$ or $\frac{36}{36}$.

Nine engagements for the turret carriage between the shafts *XII* and *XVI* are accomplished by means of two triple cluster gears with the same gearing ratios as above.

The apron of the cross slide carriage transmits motion from feed rod *XV* to shaft *XX* of the rack pinion through the reversing unit with gears $\frac{30}{46}$ or $\frac{30}{30} \times \frac{30}{46}$, worm gearing $\frac{3}{30}$ and gears $\frac{21}{60}$. This arrangement provides for longitudinal feed of the cross slide. Feed of the cross slide (cross feed) is effected by transmitting motion from feed rod *XV* to the cross feed screw *XXIV* ($t = 10$ mm) through the reversing unit, worm gearing, gears $\frac{42}{42}$ and gears $\frac{48}{23} \times \frac{23}{18}$.

This gear train provides 18 cross feeds.

The apron of the turret saddle is similar to that of the cross slide carriage. Longitudinal feeds of the turret are obtained through the following gear

train: feed rod XVI, reversing unit with gears $\frac{30}{30} \times \frac{30}{30} \times \frac{30}{46}$ or $\frac{30}{30} \times \frac{30}{46}$, shaft $XXVII$, worm gearing $\frac{3}{30}$, gears $\frac{21}{60}$, shaft $XXXI$ and rack pinion $12T$.

No provision has been made for cross feed of the turret.

The longitudinal and cross feeds are engaged by claw clutches C_4, C_5 and C_6, located in the aprons.

The rapid traverse mechanism serves for rapid approach and withdrawal of the cross slide and turret. A separate motor transmits rotation to the rapid traverse shaft along the following gear train: motor, shaft $XXXVI$, gears $\frac{18}{27}$, shaft $XXXVII$, worm gearing $\frac{2}{30}$, shaft $XXXVIII$, chain drive $\frac{15}{16}$ and shaft XIV. Each of the two aprons houses mechanisms which transmit rotation from shaft XIV to the corresponding rack pinions along the gear train: shaft XIV, gears $\frac{38}{38}$, reversing unit with gears $\frac{36}{36}$, gears $\frac{42}{60}$ and rack pinion $12T$.

The turret of the lathe is indexed by hand and is linked through bevel gears $\frac{24}{24}$ with the six-position stop spool carrying adjustable stops which automatically disengage the longitudinal feed of the turret at a preset length of travel for each turret position.

Spindle speeds and tool feeds are changed for each operation element by a preselector arrangement.

The jaw clutches are engaged and disengaged, and the sliding cluster gears are shifted by means of hydraulic cylinders. During gear shifting the shafts of the speed and feed gearboxes are slowly rotated by special mechanisms.

The lathe is braked by a multiple-disk friction brake operated by a hydraulic cylinder. The bar feed and clamping mechanisms are also controlled hydraulically.

3-5. Turret Lathe, Model 1П326

The model 1П326 turret lathe is used for turning work from bar stock or from blanks held in a chuck, with carbide-tipped or high-speed steel tools. The bar capacity is 25 mm; the maximum diameter of workpiece accommodated over the bed is 320 mm.

The lathe has a hexagon turret with a vertical axis of rotation. The gearing diagram of the lathe is shown in Fig. 79.

The speed gearbox (reducing gear) imparts six forward and six reverse speeds to the spindle in the range from 200 to 3,350 rpm. The spindle is reversed by reversing the drive motor.

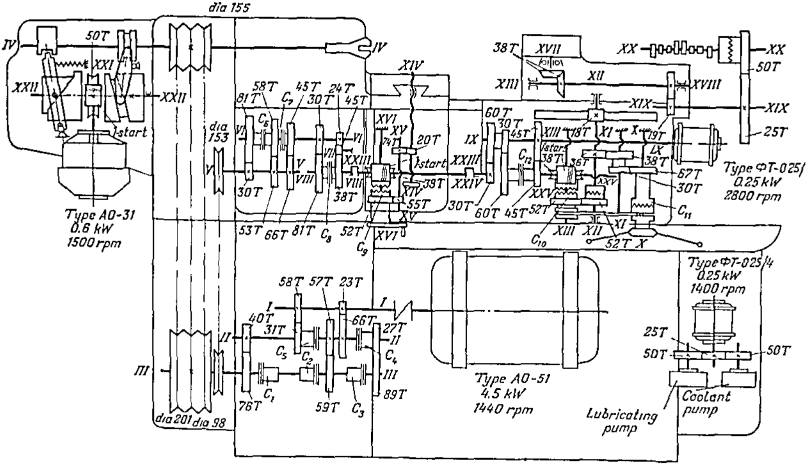


Fig. 79. Gearing diagram of the model 1П326 turret lathe

Spindle speeds are obtained along the following gear train: motor running at 1,440 rpm, shaft I, gears $\frac{23}{66}$ or $\frac{58}{31}$, shaft II, gears $\frac{27}{89}$ or $\frac{57}{59}$ or $\frac{40}{76}$, shaft III, V-belt drive with pulleys $\frac{201}{155}$ and the spindle.

The required spindle speed is obtained by the engagement of two electromagnetic clutches in various combinations. The electromagnetic clutches C_1, C_2, C_3, C_4 and C_5 are built into the reducing gear for changing speeds.

The cross slide has only cross feed; the turret has only longitudinal feed. The feed gearbox provides for three feeds for each unit.

The kinematic chain linking the spindle with the input shaft V of the feed gearbox consists of two belt drives with a total ratio $i = \frac{155}{201} \times \frac{98}{153} = 0.495$.

The feed gearbox provides for three engagements between shafts V and $VIII$ and for reversing by means of the gears $\frac{30}{81}$ or $\frac{53}{58}$ or $\frac{66}{45}$, and the reversing unit gears $\frac{30}{81}$ or $\frac{24}{45} \times \frac{45}{38}$.

The required rates and directions of feed are obtained by engaging two electromagnetic clutches in various combinations. For this purpose three clutches, C_6, C_7 and C_8, are provided in the feed gearbox (C_6 and C_8 are twin clutches).

The cross slide apron transmits motion from the feed gearbox to cross feed screw XIV along the following gear train: shaft $VIII$, worm gearing $\frac{1}{38}$, shaft XVI, gears $\frac{52}{55}$, shaft XV, and gears $\frac{74}{20}$ to cross feed screw XIV. Cross feed is engaged by means of claw clutch C_9.

The turret saddle apron is designed to transmit motion from the feed gearbox to the rack pinion $18T$ by the gear train: shaft $XXIV$, gears $\frac{30}{60} \times \frac{30}{60}$, shaft XXV, worm gearing $\frac{1}{38}$, shaft $XIII$, gears $\frac{52}{52}$, and shaft XII to the rack pinion. Longitudinal power feed is engaged by means of claw clutch C_{10}, hand feed claw clutch C_{11} being simultaneously disengaged by an interlocking arrangement.

The turret saddle has a mechanism for rapid return of the turret to the initial position. Rotation is transmitted from a separate motor (0.25 kW, 2,800 rpm) through shaft IX, gears $\frac{45}{45}$ to shaft XXV and further to the rack pinion along the gear train indicated above.

At the end of the working feed of the turret the twin electromagnetic clutch C_{12} disengages the feed gear train and engages the train for rapid return to the initial position.

The hexagon turret indexes automatically during rapid return of the saddle. The drum of a special electric control unit mounted on shaft XX turns together with the turret. The drum carries stops which operate limit switches in the supply circuits of the electromagnetic clutches in the speed and feed gearboxes. In conjunction with the electromagnetic clutches, the control unit enables a new spindle speed, cross slide feed and turret feed to be obtained for each indexing of the turret in accordance with the preset values (automatic controls).

The bar feed and clamping mechanism has an electromechanical drive.

3-6. Standard and Special Accessories for Turret Lathes

Cutting tools used to machine the blank in a turret lathe are clamped on the cross slide and in the tool holes of the turret with the aid of various holders and attachments.

The service manuals of Soviet machine tools list the standard attachments and other accessories furnished with the machine. Typical standard holders and attachments are illustrated in Fig. 80.

Setups for a definite part or a group of parts of similar shape may include special attachments (Fig. 81) furnished with the turret lathe on special order only.

The processing capacities of a turret lathe are extended by various attachments, such as the plain threading attachment with a leader clamped to the

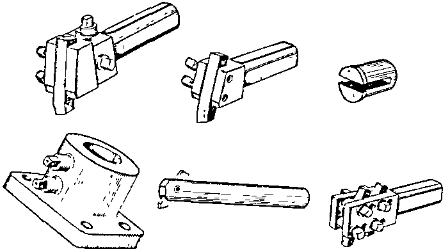


Fig. 80. Standard holders and attachments for turret lathes

turret lathes. Generally accepted distinguishing features of vertical turret lathes are the turret on the main tool head and the turreted toolholder on the side head. A vertical boring mill usually has two ram-type tool heads on the crossrail. The horizontal position of the work-holding surface of the circular table (also called a chuck in the vertical turret lathe because of its adjustable jaws) rotating about a vertical axis facilitates the setting up and clamping of large, heavy workpieces. Considerable difficulties may be encountered in attempting to machine such work in engine or facing lathes.

Both vertical boring mills and vertical turret lathes perform turning and boring operations on external and internal surfaces of various contours with single-point tools. Machines with a turret, i.e., vertical turret lathes, can machine the central hole in a blank with twist drills, core drills, taps, and other tools.

Milling, grinding and slotting can also be done if the corresponding special attachments are installed.

The main dimensions of vertical boring mills and vertical turret lathes are the *maximum diameter of workpiece accommodated* when the side tool head is in its lower position, and the height of the work admitted.

Brief specifications of all Soviet models are listed in Table 9.

In addition to the models listed in Table 9, heavy vertical boring mills that can machine diameters up to 20-25 *m* are to be manufactured in the USSR in the next few years.

In addition to the general-purpose models, Soviet industry manufactures single-purpose vertical boring machines with an annular table (for ring-type work) and tower models for boring holes in work of large diameter.

3-8. Working and Auxiliary Motions in Vertical Turret Lathes and Vertical Boring Mills

The primary cutting motion (v) in this type of machine is rotation of the table carrying the work (Figs. 82 and 83). The feed motions are the horizontal and vertical travel (s_1, s_2, s_3 and s_4) of the tool heads on the crossrail and the side heads.

Auxiliary motions include rapid vertical traverse of the crossrail, indexing of the turret, etc.

Vertical feed of the side head is employed to turn external surfaces of various contours; the horizontal feed is used in cutting grooves, chamfering, etc. The horizontal feed of the crossrail heads is employed in facing operations; their vertical feed, for turning and boring external and internal surfaces.

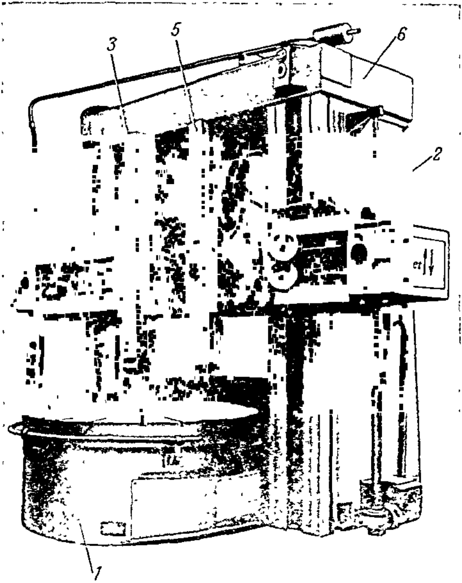


Fig. 82. Double-housing vertical boring mill, model 1M553

3-9. Construction Arrangement and Principal Units

In construction arrangement these machines can be classified as single- and double-housing types.

The single-housing, or column, models (Fig. 83) are usually vertical turret lathes and are available for machining work up to 1,600 mm in diameter.

The principal units are bed and column *1*, table (chuck) *2*, crossrail *3*, swivelling ram *4* with a five-sided turret, side head *6*, table drive, and tool head feed mechanisms *5*.

The double-housing models (Fig. 82) are available for machining work up to 25,000 mm in diameter. Two housings *2* are secured to bed *1* and are linked together at the top by arch *6*. Travelling vertically on the ways of the housings is crossrail *4* carrying two tool heads *3* and *5*. Here, both are ram-type heads but on models machining work up to 2,300 mm in diameter one head may be equipped with a turret.

The other units are similar to those of single-housing models.

Table 4 (or *chuck*) is the most typical unit of these machine tools. With its circular ways *3* (Fig. 84) the table bears on ways *2* of the bed. Spindle *1*, mounted in antifriction bearings *5* and *6*, ensures precise location of the table. Ball thrust bearing *7* reduces the pressure in the circular ways when the table is rotating at high speeds. This is accomplished by the rotation of worm *8*, worm wheel *9* and threaded collar *10*, thereby raising the spindle and table a very slight amount. The circular ways are relieved of a part of the axial and radial loads, which are taken up by bearings *5* and *6*.

In certain designs the table is raised for the same purpose by a hydraulic cylinder.

High-speed vertical turret lathes, intended for machining light alloys, do not have circular ways and the loads are carried by roller bearings *1* and *3* on the spindle and ball thrust bearings *2* (Fig. 85).

The table is driven through bevel gears *4* and *5*, and spur gears *6* and *7*.

The *table drive* in the small- and medium-size models consists of a single-*speed motor and a speed gearbox.*

The latest models of light-duty vertical turret lathes have speed gearboxes with built-in electromagnetic clutches that automatically change the table speeds in accordance with turret indexing on the head.

The main drive of heavy vertical boring mills consists of a variable-speed d-c motor, providing stepless table speeds, and a speed gearbox with a small number of speed steps. For example, if the speed gearbox has three steps, the table will have three speed ranges with infinitely variable speeds in each range.

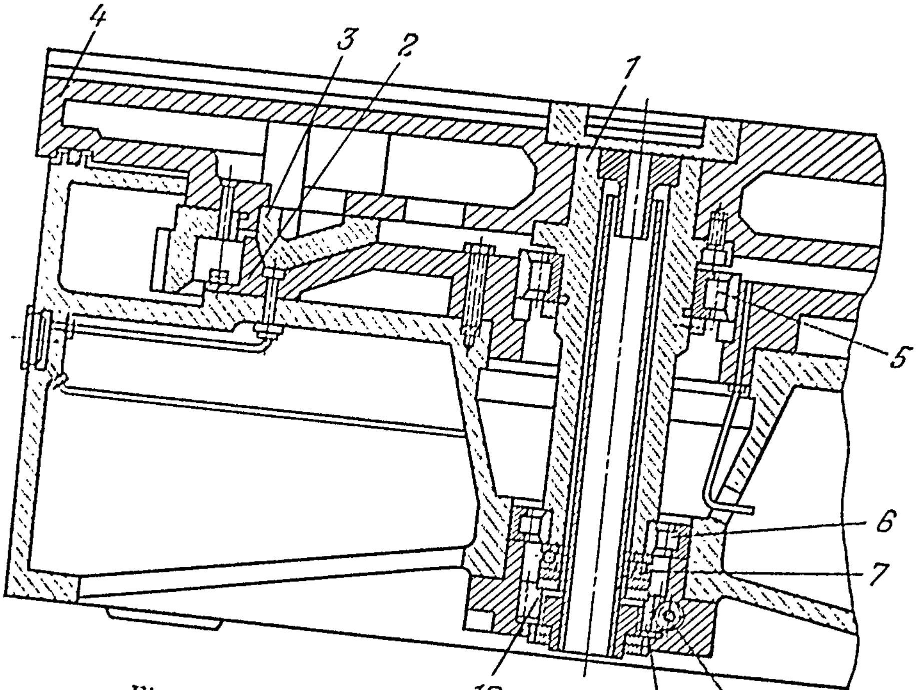


Fig. 84. Work table of a vertical boring mill

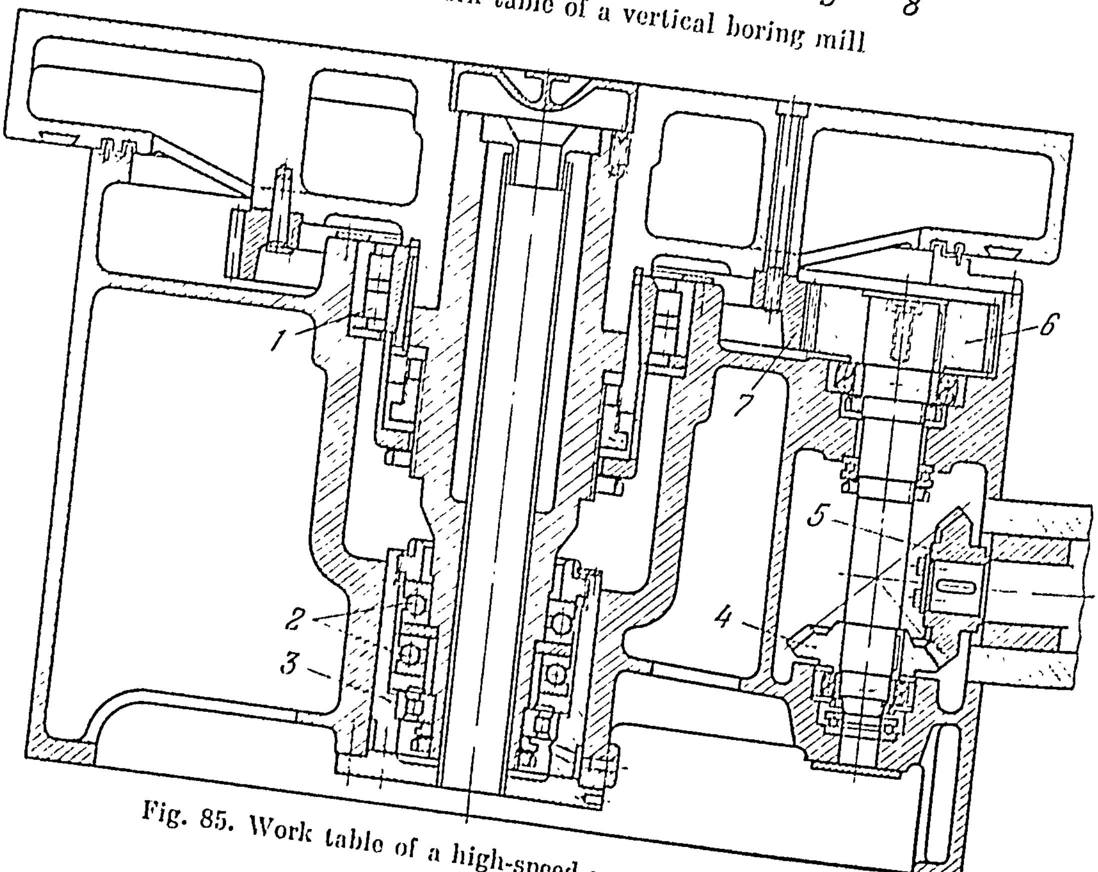


Fig. 85. Work table of a high-speed vertical turret lathe

The *feed mechanisms* of the tool heads are feed gearboxes mounted directly on the side head or on the ends of the crossrail and linked through a gear train to the table. Electromagnetic clutches in the feed gearboxes of the newer models of vertical turret lathes enable feeds to be automatically changed according to turret indexing, and contouring to be performed to a template.

Almost all the models have mechanisms providing rapid traverse movements of the heads and crossrail; in the small vertical turret lathes these mechanisms are powered by a single motor. In the heavy machines, each rapid traverse mechanism has a separate drive.

Pendent push-button control on both vertical turret lathes and boring mills provides more convenience in operation. Many of the newer vertical turret lathes are equipped with facilities for operating with an automatic cycle.

3-10. Accessories for Vertical Turret Lathes and Boring Mills

In the great majority of cases the work is set up and clamped directly on the table. Various accessories are used, including screw jacks, strap clamps, bolts, sets of strips and spacers, adjustable chuck jaws, etc. (Fig. 86).

Parts of comparatively small size can be held in a chuck mounted on the table.

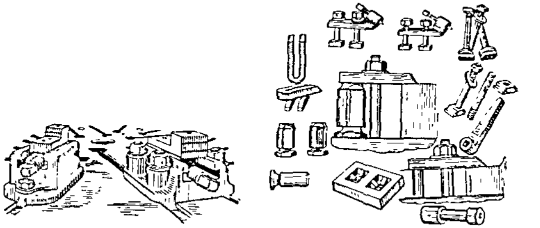
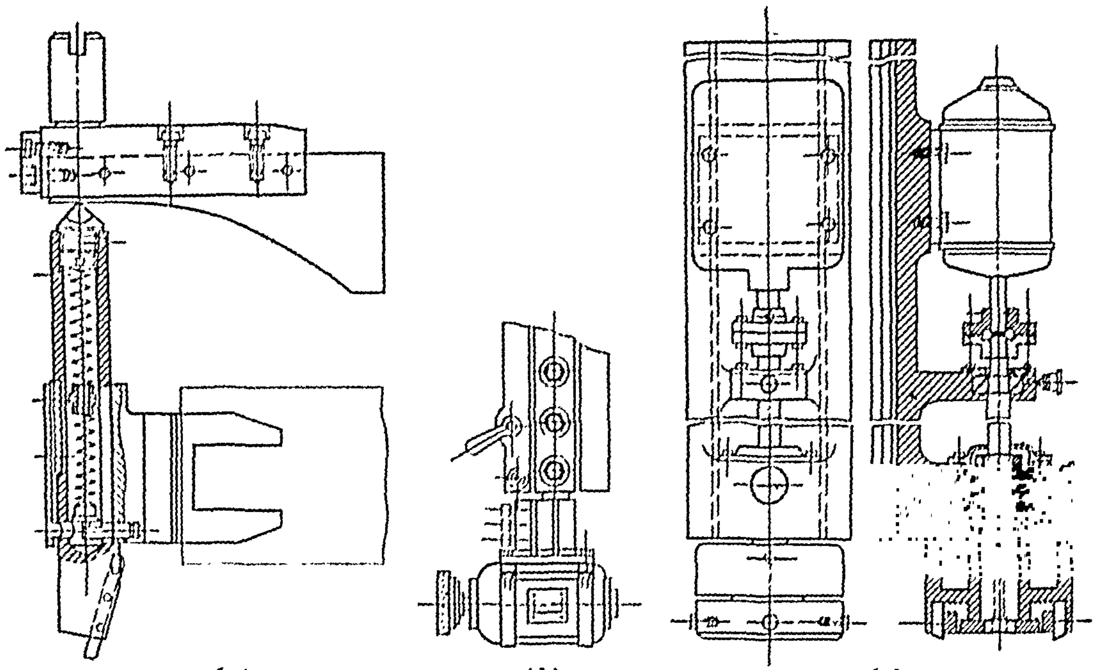


Fig. 86. Accessories for setting up and clamping work in vertical turret lathes and boring mills



(a) (b) (c)

Fig. 87. Attachments for vertical turret lathes and boring mills: (a) contouring; (b) surface grinding; (c) milling

Many attachments (Fig. 87) are available for extending the processing capacities of these machines. They are mounted either on the turret or in place of it.

Cutting tools are clamped in the turret by means of accessories similar to those described in Sec. 3-6.

The side head carries a square turret, as a rule, and can clamp up to four single-point tools.

CHAPTER 4

AUTOMATIC AND SEMIAUTOMATIC LATHES

4-1. Purpose of Automatic and Semiautomatic Lathes

An *automatic machine tool* is one in which all working and auxiliary motions, needed to carry out a definite sequence of machining operations, including loading of the blank and unloading of the finished workpiece, are performed automatically. The only attention required from the operator is to load new blanks into the magazine or hopper periodically (or to feed new bars into the machine) and to inspect the finished work.*

A *semiautomatic machine tool* is one in which all the working and auxiliary motions, comprising the cycle for machining one piece, are performed automatically. At the end of the cycle the machine stops automatically. To repeat the cycle, the completed piece must be removed, a new blank loaded, and the machine started again.

Automatic and semiautomatic lathes can produce parts of complex shape by machining the blank (or bar stock) with a whole series of cutting tools.

In addition to automatic and semiautomatic lathes, extensively applied in the engineering industries, automatic and semiautomatic milling, grinding, drilling and other machines are also available.

The operating cycle of modern machine tools is automated on the basis of a control system employing mechanical, hydraulic, electrical, electronic, or pneumatic facilities, or any combination of these.

Machine tools in which automaticity is achieved by mechanical means are productive and dependable in operation. Much time, however, is lost in changing over from one job to another. Therefore, automatic machine tools of this type are used, as a rule, in mass production, and semiautomatics—in lot and large-lot production. Machine tools automated by other than mechanical means can be set up for new jobs much more rapidly and can therefore be efficiently employed in lot production.

Machine tools with numerical (programmed) control of the operating cycle, using stored numerical data on tape or punched cards, are an exception among automatic machine tools since they can produce small or medium lots to advantage (see Vol. IV, Part Six).

*When bar stock is used, the blank is considered to be the part of the bar of which one workpiece is made.

Automatic and semiautomatic lathes are classified according to various features such as:
(a) purpose—into general- and single-purpose machines;
(b) the type of blank—into bar and chucking machines;
(c) the number of spindles—into single- and multiple-spindle models;
(d) the arrangement of the spindle—into horizontal and vertical models.

4-2. Cam Drives and Groups of Automatics

This chapter deals mainly with automatic and semiautomatic lathes in which automaticity is achieved by mechanical means based on *cam drives.* Automatic control of the operating cycle is effected with the aid of a *camshaft* carrying cams of various shape linked through a system of levers, gears and other transmissions to the operative mechanisms (slides, clamping and feeding mechanisms, etc.). Upon rotation of the camshaft, the cams actuate the various operative mechanisms. The sequence of the motions is determined by the arrangement of the cams on the camshaft. As a rule, one blank is completely machined during one revolution of the camshaft.

Cams are classified according to their forms as *plate cams* (Fig. 88*a*) and *cylinder cams* (Fig. 88*b*).

Plate cams, also called edge or disk cams, can conveniently transmit motion with a short stroke and in a plane square to the axis of rotation of the cam. Cylinder, or cylindrical, cams are usually used to transmit motion with a considerably longer stroke and in a plane parallel to or passing through the axis of rotation of the cam.

In their construction cams can be classified as solid and removable-strap types. One modification of the cylinder cam is the single-edge type which is a hollow cylinder with a curved edge on one end.

As regards certain features of their cycle control, automatic lathes can be divided into three groups.

The *first group* includes automatics with a single camshaft which controls both main (working) and auxiliary (idle) motions and which rotates at a *speed constant for the given setup.* Considerable losses of time on the idle motions are inevitable for the machines of this group since the speed of the camshaft is determined by the slow working motion (working feed). However, in small automatics with only few idle motions this procedure is expedient and is justified by its simplicity.

The *second group* of automatics also has a single camshaft but in the cousre of the cycle two speeds of rotation—slow and rapid—are imparted to it. All the working motions are performed during slow rotation of the camshaft, and all idle motions, during rapid rotation. Though the advantages of this arrangement are self-evident it has a drawback in that it is impossible to

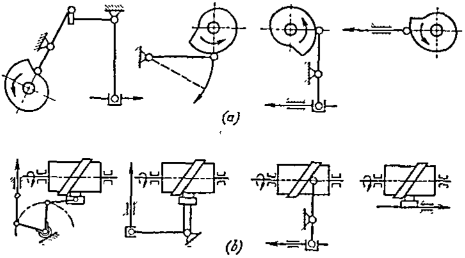


Fig. 88. Cams:
(a) plate cams, (b) cylinder cams

obtain a substantial difference between the two speeds of camshaft rotation. This is due to the fact that the camshaft with the whole set of working and idle cams has quite a large moment of inertia, leading to impact loads in the change-over mechanisms when switching over from one speed to the other. Automatics designed for comparatively few idle motions operate on this principle.

The *third group* is made up of automatics having a high-speed auxiliary camshaft for actuating the idle motions in addition to the main camshaft which rotates at a slow speed and provides for all working motions as well as control of the cycle. Drums with dogs on the main camshaft transmit the commands for the performance of the idle motions. This principle finds application in automatics intended for machining work of the most complex shape for which a great many auxiliary motions are required.

4-3. Single-Spindle Automatics

The most extensively used types of single-spindle automatics are the *automatic cutting-off machine*, *Swiss-type automatic screw machine*, and *single-spindle automatic screw machine*.

Automatic cutting-off machines are designed to produce short parts of small diameter and simple shape from bar or coil stock in large-lot and mass production. The principle of operation of such an automatic is illustrated in Fig. 89.

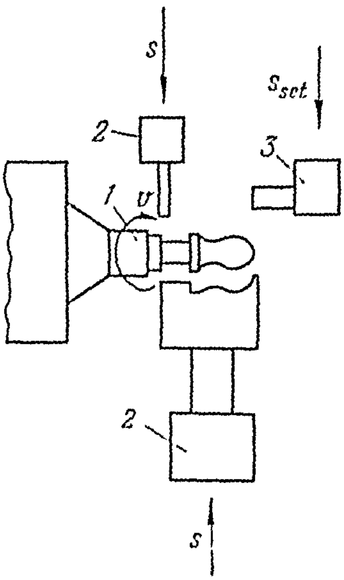


Fig. 89. Principle of an automatic cutting-off machine

The stock is clamped in the collet chuck of the rotating spindle *1*. The machine has from two to four slides *2* operating only in the crosswise direction and carrying form and cut-off tools. To obtain work of the specified length, the automatic has a movable stock stop *3* which is automatically advanced in line with the spindle axis at the end of the cycle. The stock is fed out by the bar feeding mechanism up to the stop.

This automatic can be referred to the first group.

The primary cutting motion (v) in these machines is spindle rotation; the feed motion (s) is the travel of the slides.

Certain models of automatic cutting-off machines have an end-working tool slide, travelling along the spindle axis and used in drilling holes. Typical parts produced by automatic cutting-off machines are shown in Fig. 90.

Swiss-type automatic screw machines are intended for producing long parts of small diameter from bar or coil stock in mass production. These automatics are chiefly used in the precision industries, for example, in the manufacture of watches, instruments, radio parts, etc.

The high requirements made by the precision industries to the accuracy and surface finish of the machined parts have given rise to a number of the construction features of Swiss-type automatics. Figure 91 illustrates the principle of operation of this machine. The stock is clamped in rotating spindle *1* in a collet chuck. Headstock *2* moves along ways on the bed thereby imparting longitudinal feed motion (s_1) in reference to the tool *8* clamped in rest *9*. The tool rest is mounted on a support which moves back and forth in a stationary carriage on the bed. The tool support is actuated by a rocker arm and lever from a cam controlling radial tool movements and providing for advance or retraction of the tool when going over to the turning of steps of different diameters, and for cross feed (s_2) in forming or cutting-off operations. The automatic has two or three vertical tool rests arranged radially, and rocker *4* carrying two tools and having a rocking motion about pin *5*. The arrangement of the tool rests and rocker is shown in Fig. 92.

The machining of the central hole, i.e., drilling, enlarging, cutting thread with taps or dies, etc., is done with the aid of special attachments *7* (Fig. 91) mounted on the left-hand side of the bed.

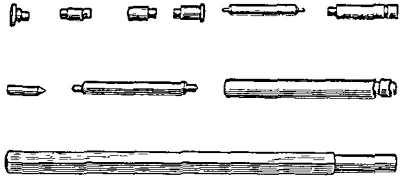


Fig. 90. Typical parts produced by automatic cutting-off machines

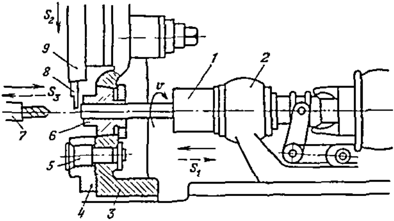


Fig. 91. Operation of a Swiss-type automatic screw machine

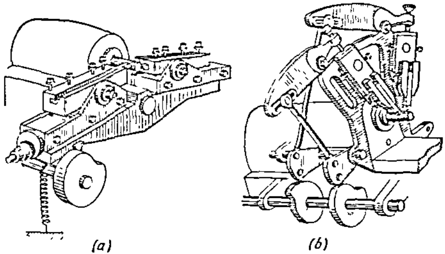


Fig. 92. Arrangement of tool rests and rocker slide in Swiss-type automatics.
(a) rocker, (b) vertical tool rests

The spindles of such attachments are frequently designed with independent axial feed (s_3) and rotary motion. The front end of the bar stock passes through the precise hole of guide bushing *6* which is mounted in tool carriage *3* secured on the bed. Thus, the tools operate immediately in front of the stock guide, and vibration and bending of the bar due to the action of the cutting force are substantially reduced. Parts of considerable length can be turned with this arrangement at a high rate of production. The dimensional accuracy and surface finish of parts produced by this automatic are very high.

It should be noted that the bar stock used in these machines must be of fairly high accuracy; best results are obtained by using centreless-ground bars.

The primary cutting motion (v) is the rotation of the spindle. In turning a cylindrical surface the longitudinal feed motion s_1 is the travel of the headstock. Cross feed s_2 in cutting off is provided by motion of the vertical tool rests or by movement of the rocker. If a contour is generated by simultaneous motion of the headstock and cutting tool, the feed is the geometrical sum of the longitudinal and cross feeds (s_1 and s_2).

In drilling from the solid, core drilling or reaming, the longitudinal feed is the algebraic sum of the longitudinal feeds of the headstock spindle and attachment spindle, s_1 and s_3.

Swiss-type automatic screw machines have a single camshaft which controls both the working and idle movements (first group of automatics).

Figure 93 illustrates typical parts produced by Swiss-type automatics. The principal dimensional data on up-to-date Soviet models of this class of machine tool are listed in Table 10.

TABLE 10

Model	Bar capacity, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.
1103	4	1,600 to 12,500	1.1	400
1Б10П	6	1,400 to 10,000	1.5	610
1А12П	10	900 to 8,000	2.2	800
1И16	16	400 to 5,600	3	1,200
1И25	25	250 to 4,000	5.5	1,600

Single-spindle automatic screw machines are designed for the mass production of finished parts of complex shape from bar stock.

Work efficiently handled by these automatics requires the use of a great number of different cutting tools which are accommodated on the six-posi-

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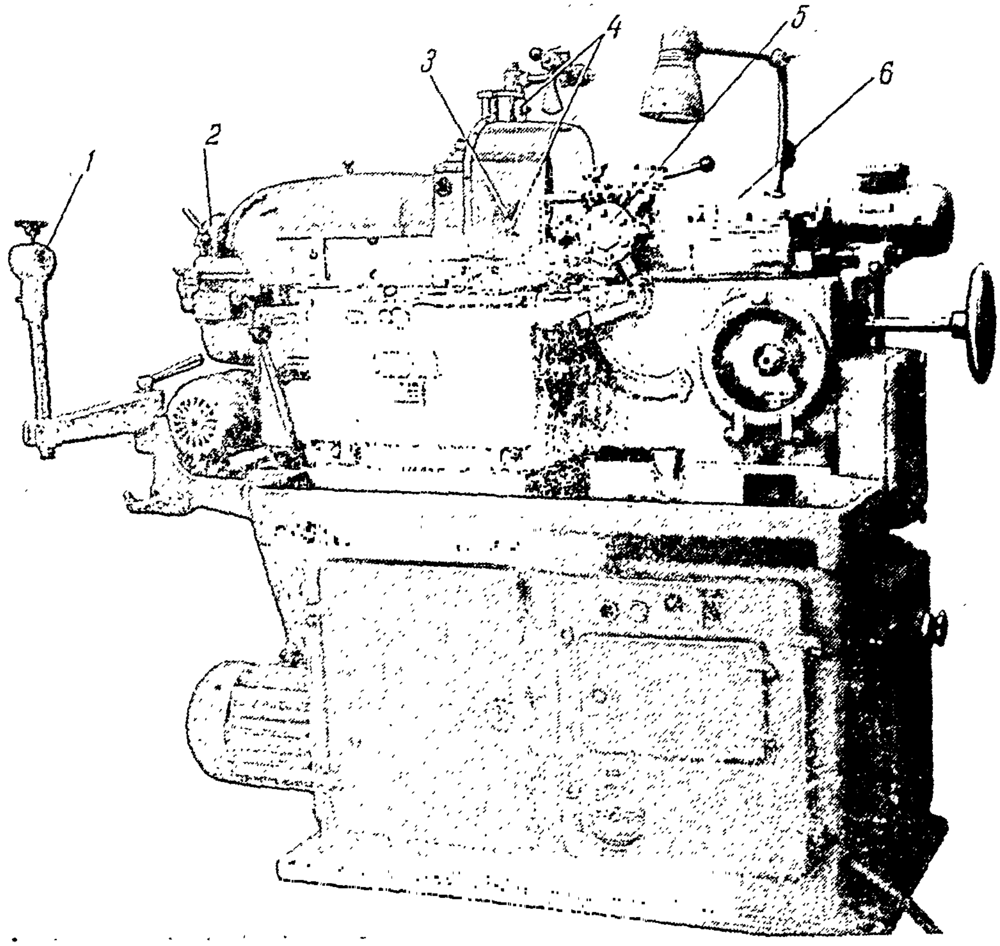
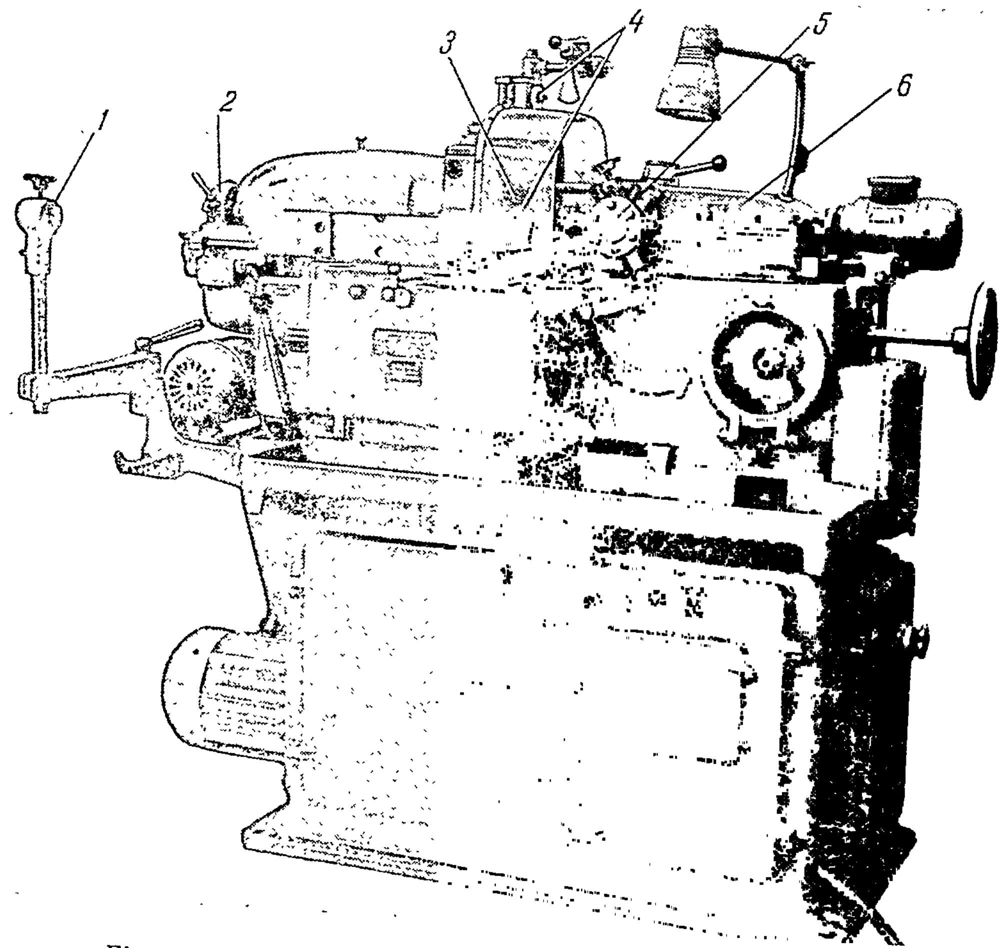


Fig. 94. Single-spindle automatic screw machine, model 1Б118

to exclude the possibility of interference of the next tool with the work (if the next tool is longer). The automatic has a camshaft which actuates all working and a part of the auxiliary motions; it also controls all the remaining auxiliary motions (third group). Plate cams actuate the working motions of cross slides *4*. The slides are withdrawn by springs to the initial position in accordance with the profiles of their cams.

Lead cam *1* (Fig. 95), located between the bed ways and mounted on the lead camshaft, a branch of the main camshaft, actuates the turret slide through a lever and rack drive at the given rate of feed. Spring *2* withdraws the slide to its initial position when the roller reaches a low point on the cam.



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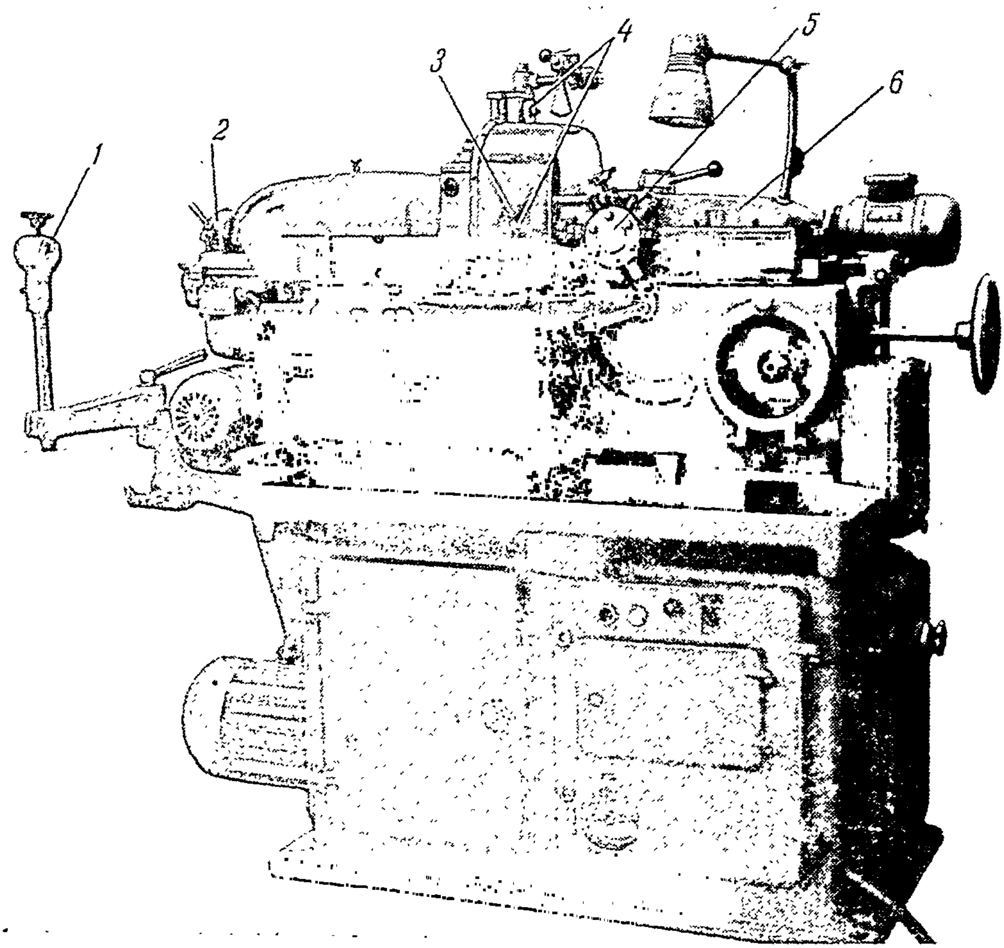

Fig. 94. Single-spindle automatic screw machine, model 1Б118

to exclude the possibility of interference of the next tool with the work (if the next tool is longer). The automatic has a camshaft which actuates all working and a part of the auxiliary motions; it also controls all the remaining auxiliary motions (third group). Plate cams actuate the working motions of cross slides *4*. The slides are withdrawn by springs to the initial position in accordance with the profiles of their cams.

Lead cam *1* (Fig. 95), located between the bed ways and mounted on the lead camshaft, a branch of the main camshaft, actuates the turret slide through a lever and rack drive at the given rate of feed. Spring *2* withdraws the slide to its initial position when the roller reaches a low point on the cam.

The turret is indexed, and the bar is fed out and clamped by special mechanisms actuated by cams on high-speed auxiliary camshaft *1* (Fig. 96) at the rear of the machine.

Jaw clutch *3* engages the transmission of rotation from the auxiliary camshaft to the turret indexing mechanism through gears *2*, *8* and *7*. When clutch *4* is engaged, the bar feeding and clamping mechanism is driven by the auxiliary camshaft through gears *5* and *6*. Engagement of the jaw clutches is controlled from trip dog carriers (drums) (Fig. 97) through a system of levers.

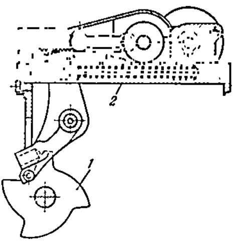

Fig. 95. Operation of the turret slide in automatic screw machines

The operation of the jaw clutch for engaging the turret indexing gear train is shown in Fig. 97.

Carrier *1*, keyed on the main camshaft, has a trip dog *2* which can be adjusted circumferentially in a T-slot. This trip dog turns lever *3* on the other end of which teat *4* of a screw is pulled out of the groove in sliding clutch member *5*. This releases the clutch member so that spring *6* forces its teeth into engagement with those of clutch member *8* which is fixed on the auxiliary camshaft by dowel pin *7*

The jaw clutches are disengaged at the end of the cycle of auxiliary motion that they control

Machining of the work consecutively with a number of different tools requires, as a rule, changes in the speed and direction of spindle rotation during the cycle. In designs of automatics with mechanical controls, a carrier on the main camshaft has trip dogs which operate the mechanisms for changing the speed and reversing the spindle This is accomplished as in the previous case by the engagement of a jaw clutch on the auxiliary camshaft which imparts the necessary motion to the speed-changing mechanism.

The *speed gearboxes* of automatic screw machines of the latest design have built-in electromagnetic friction clutches which provide the required spindle speed when engaged in the corresponding combination. Changes in spindle speeds are co-ordinated with turret indexing by means of a special electrical control unit set up beforehand to the required operating cycle.

Typical parts produced by automatic screw machines are shown in Fig. 98.

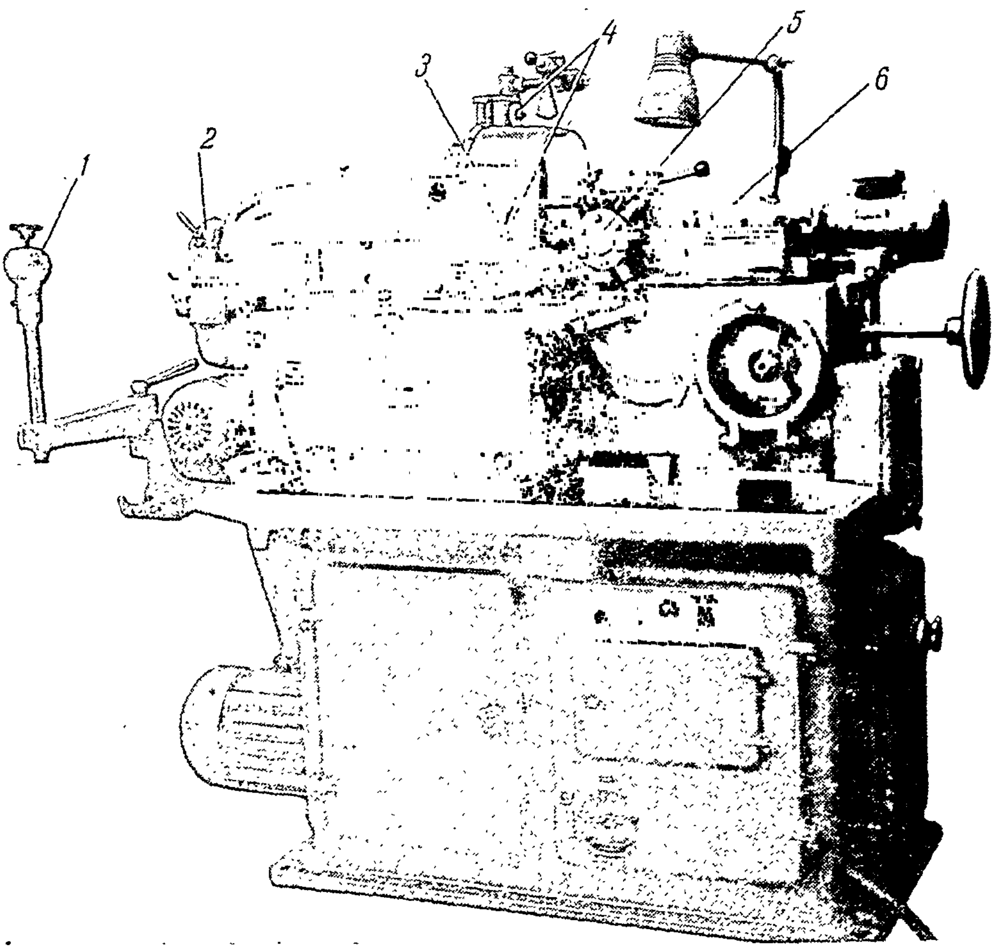

Fig. 94. Single-spindle automatic screw machine, model 1Б118

to exclude the possibility of interference of the next tool with the work (if the next tool is longer). The automatic has a camshaft which actuates all working and a part of the auxiliary motions; it also controls all the remaining auxiliary motions (third group). Plate cams actuate the working motions of cross slides *4*. The slides are withdrawn by springs to the initial position in accordance with the profiles of their cams.

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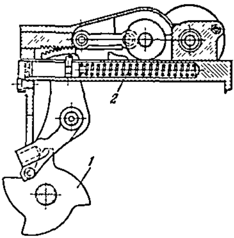

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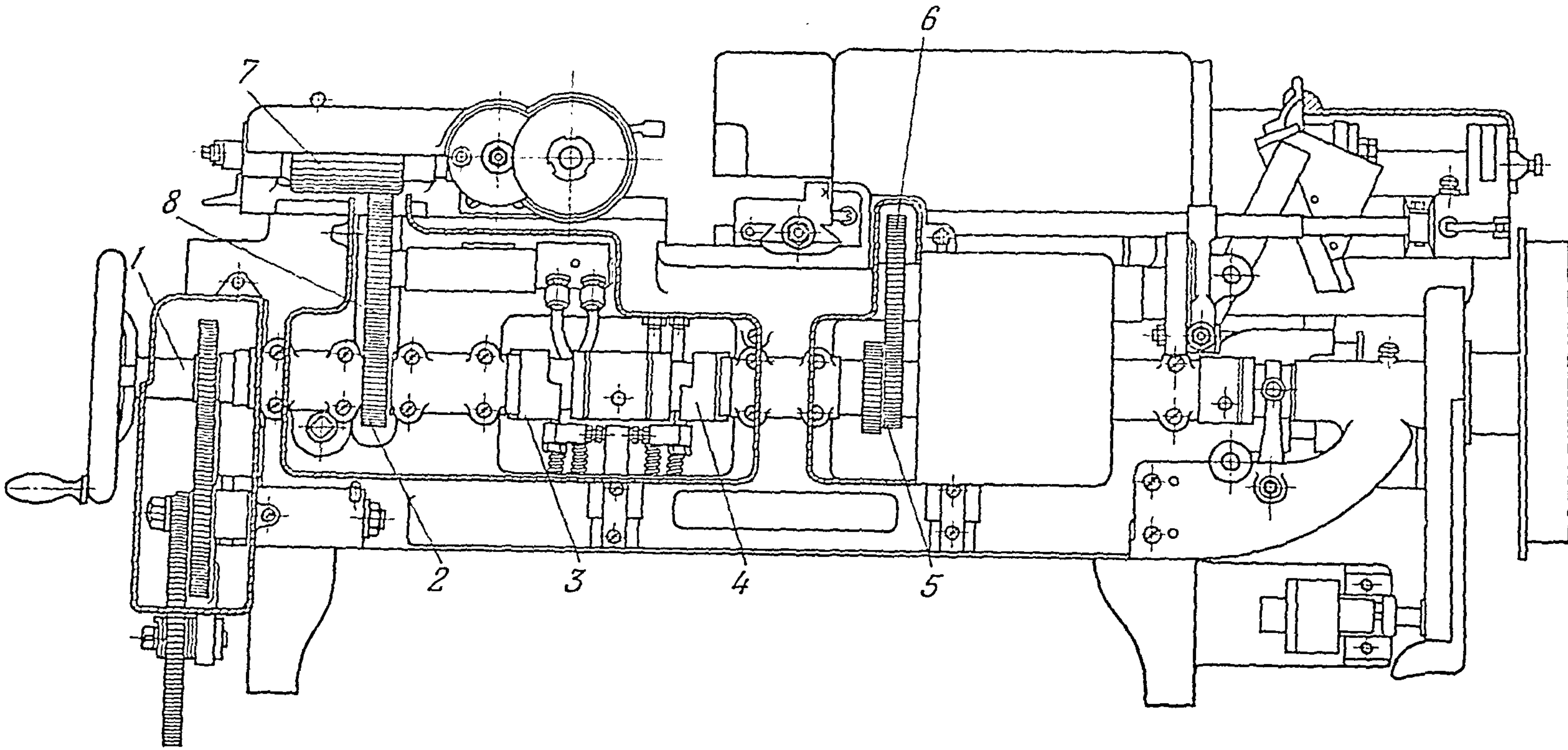


Fig. 96. Automatic screw machine (viewed from the side of the auxiliary rear camshaft)

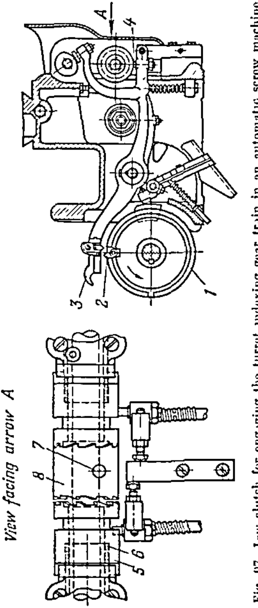


Fig. 97. Jaw clutch for engaging the turret indexing gear train in an automatic screw machine

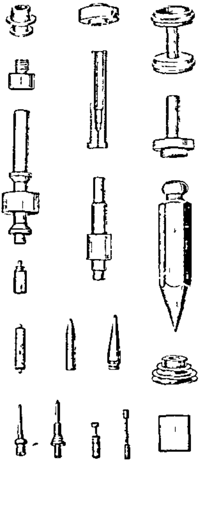


Fig. 98. Typical parts produced by automatic screw machines

The principal dimension of these automatics is the bar capacity. The main dimensional data on up-to-date models of automatic screw machines manufactured in the Soviet Union are listed in Table 11.

TABLE 11

Model	Bar capacity, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.
1Б112	12	475 to 5,900	2.2	1,020
1Б118	18	375 to 4,675	2.2	1,050
1Б125	25	200 to 3,150	5.5	2,300
1Б136	36	160 to 2,500	5.5	1,750
1Б140	40	160 to 2,500	5.5	2,300
1165	65	50 to 1,600	10	3,000

4-4. Multiple-Spindle Horizontal Automatic Bar and Chucking Machines

Multiple-spindle automatics are designed for the mass production of parts from bar stock or separate blanks, the distinguishing characteristic being that several workpieces are machined at the same time from as many bars or blanks. As to the type of stock or blanks they machine, they are classified as *bar-type* and *chucking* (*magazine*) machines.

According to their principle of operation, horizontal multiple-spindle automatics are classified as *parallel-* and *progressive-action*.

In the parallel-action automatics the same operation is performed simultaneously in all the spindles. Thus, during one operating cycle, as many workpieces are completed as there are spindles. Such machines are used for producing comparatively short parts of simple shape from bar stock.

A typical representative of the parallel-action automatics is the four-spindle automatic cutting-off machine, model 1240-0 (Fig. 99). This type of machine is also known as the four-spindle straight automatic bar machine.

Mounted on base *6* is headstock *2* with four rotating spindles (primary cutting motion v) arranged in one line in a vertical plane. Each spindle has stock feed and chuck operating mechanisms. The stock feed mechanism is combined with stock supporting mechanism *1* and is operated by pneumatic power. The collet chucks for clamping the bars are controlled by the camshaft. The bars are fed out to stock stops *4* held in rear upright *5*. Two cross slides *7*, each carrying tools for machining the work in all four spindles, travel in slots of the headstock. These slides have only crosswise motion (cross feed s). Form tools are clamped in one tool slide and cut-off tools in the other. The headstock and rear upright are joined together by top brace *3*

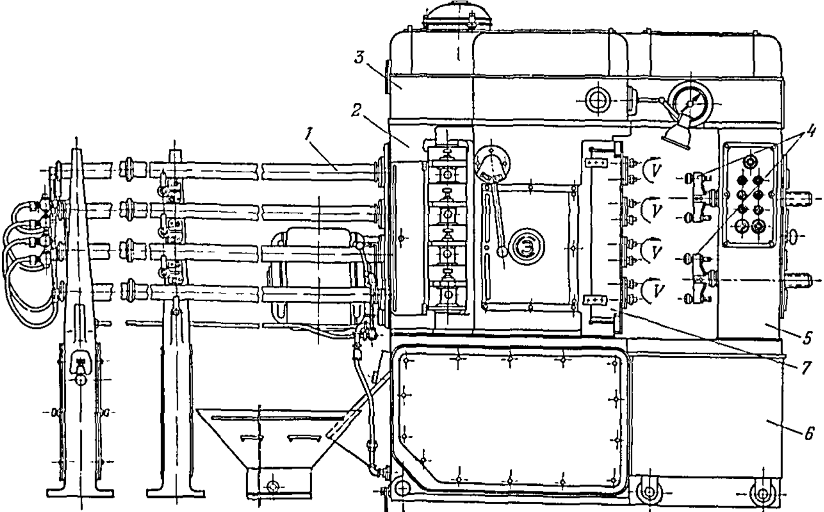
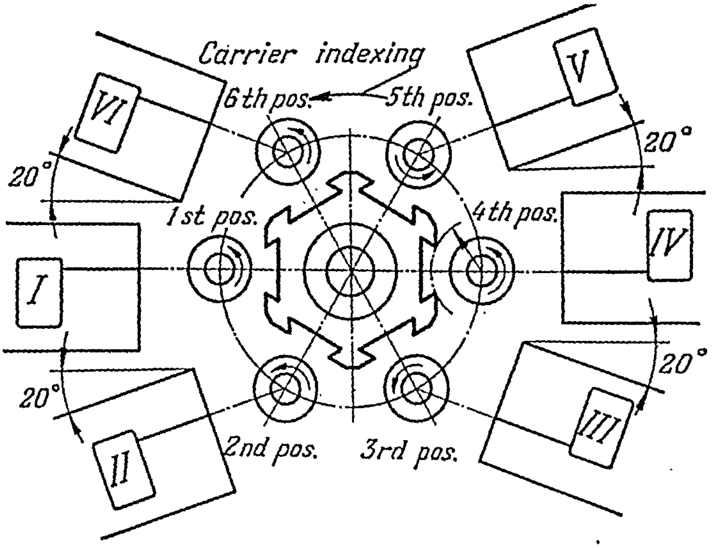


Fig. 99. Four-spindle automatic cutting-off machine, model 1240-0



. 100. Positions of a multiple-spindle progressive-action automatic

up a rigid frame. The top brace also houses the camshaft, which all working and idle motions of the operative units.
mshaft has two speeds of rotation (automatic of the second group). achines are used to produce the same type of parts made by single-utting-off machines (Fig. 93). The principal dimension of these is the bar capacity.
progressive-action automatics each spindle with its blank or stock l consecutively to all the positions. One or several operations are in each position according to the sequence of machining opera-blished in the setup (Fig. 100).
x or eight spindles are mounted in the spindle carrier which turns periodically through an angle equal to the central angle between ent spindles. The setup is designed so that the work is completely in one full revolution of the spindle carrier, one part being pro-each indexing. One of the positions is the loading or feeding posi-he bar-type machines the finished workpiece is cut off in this posi-bar is fed out to the stop and then clamped by the collet chuck. ucking (magazine) machines the finished part is released by the the loading position, a new blank is loaded into the chuck from zine and clamped.
on may be made in the design of the automatic for two loading positions (usually diametrically opposed). In this case the work rough only one half of the available positions, during which time

it is completely machined. Thus, two workpieces are completely machined at the same time during one full revolution of the carrier, two workpieces being produced at each indexing. This procedure, known as parallel-progressive-action, is applicable in making parts of simple shape at a high rate.

In the type and size range established for Soviet manufacture, multiple-spindle horizontal automatic chucking machines are referred to as semiautomatics even though the construction of the latest models incorporates facilities for magazine feed, a feature that converts such a machine into a fully automatic machine tool. This is due to the fact that a magazine feed cannot be a general-purpose device, i.e., suitable for all sizes and shapes of blanks that can be machined in the automatic. In construction these semiautomatics are almost the same as the automatics, the difference being in the manual loading of the blank and the absence of a cross (cut-off) slide in the loading position.

The principal dimension of the bar machines is the bar capacity; that of the chucking machines is the chuck diameter.

Brief specifications for Soviet automatic and semiautomatic multiple-spindle machines are listed in Table 12. Typical parts produced by these machines are illustrated in Fig. 101.

Figure 102 is the general view of a six-spindle horizontal automatic bar machine, model 1265M-6. The machine is intended for producing complex parts from bar stock with high-speed steel and carbide-tipped cutting tools.

Headstock *3* and gearbox *5* are mounted on base *1* and are linked together rigidly by top brace *4*. This frame-type design provides ample rigidity and convenient arrangement of the principal parts.

The top brace houses the camshaft which has two speeds of rotation: slow rotation for working feeds and high-speed rotation for idle motions (automatic of the second group).

The headstock contains the indexing spindle carrier in which six spindles are mounted. The spindle carrier is indexed and locked in each position

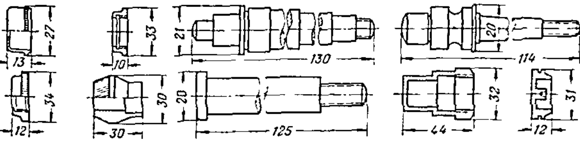


Fig. 101. Typical parts produced by multiple-spindle automatics

TABLE 12

Model	Bar capacity, mm	Number of spindles	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.	Remarks
1216-6	16	6	Up to 5,000	10	3,500	Can be built into an automatic transfer machine
1220-4	20	4	Up to 5,000	10	3,500	
1220-8	20	8	210 to 2,820	13	6,200	
1A225-6	25	6	Up to 3,500	13	5,700	
1A240-8	32	8	177 to 2,640	13	9,000	
1A240-6	40	6	141 to 2,555	13	9,000	
1A240-4	50	4	125 to 2,275	13	8,700	
1265M-8	50	8	97 to 2,200	30	13,500	
1265M-6	65	6	73 to 1,590	30	13,500	
1265M-4	80	4	61 to 1,200	22	13,000	
1A290-6	100	6	70.5 to 930	30	17,600	
1A290-4	125	4	54.5 to 810	30	17,000	

by special mechanisms driven from the camshaft. Spindle rotation (primary cutting motion v) is powered through the central drive shaft from mechanisms housed in gearbox *5*.

The bars are held in stock reel *2* and their front ends are clamped in the spindle with collet chucks controlled by the camshaft.

The bar stock is fed out in the sixth position (see Fig. 100) to the stock stop which is automatically shifted to a position in line with the spindle immediately before the bar feed and is then retracted. The movements of the stock stop and the bar feeding mechanism are also controlled by the camshaft. Six cross, or side, slides *7* travel along guides (cross feed s_2) mounted on the front end face of the headstock. Toolholders with form and cut-off tools are clamped in the slots of the cross slides. Cross slide travel is controlled from the camshaft through a lever system which enables the travel to be varied in the range from 0 to 22 mm using a constant cam (Fig. 103).

Such operations as straight turning, machining the central hole and cutting internal and external threads are performed by tools mounted on main tool slide *8* (see Fig. 102) which slides along a stem, press-fitted into the spindle carrier, and a guide on the top brace. The faces of the main tool slide have dovetail guides for clamping stationary toolholders and for guiding travelling toolholders. The motion of the main tool slide (longitudinal feed s_1) is effected from the camshaft through a special mechanism.

The main slide drive (Fig. 104) provides for rapid approach (and withdrawal) over a distance of 120 mm and working feed with a travel that can be

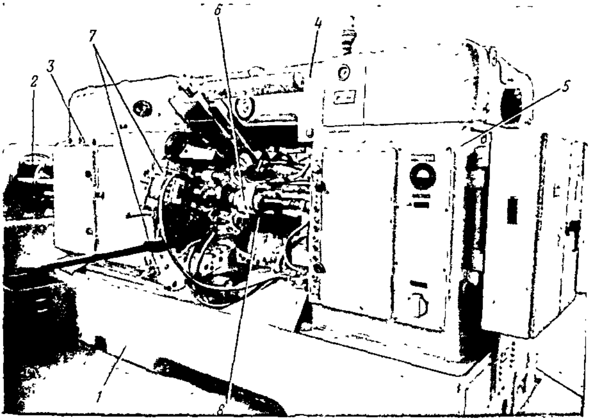


Fig. 102. Six-spindle horizontal automatic bar machine, model 1265M-6

varied in the range from 20 to 80 mm. Rapid approach and withdrawal of the main tool slide are effected by the motion of carriage *1*, linked through roll *2* with a cam on the camshaft. At this time feed lever *5* is held stationary and pinion *6*, running along rack *7*, advances rack *8*, linked to the main tool slide, over a distance twice that of carriage travel. Rapid approach continues until the carriage runs up against a stop screw (not shown in Fig. 104). Next, by means of roll *4* another cam on the camshaft actuates feed lever *5* which begins to turn slowly. The movement of rack *7* leads to movement of rack *8* and the main tool slide. The distance of travel, or stroke, of the main tool slide is set up by adjusting the position of tie-rod *3* in the slot of lever *5*, and can be read off on the adjacent scale. During rapid withdrawal, the lever and carriage return simultaneously to their initial positions.

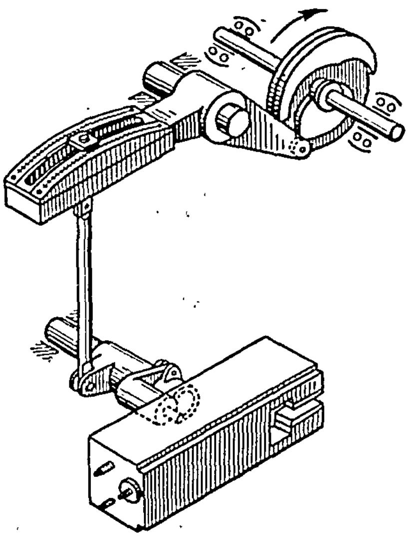


Fig. 103. Cross slide feed drive in the model 1240-6 automatic

The spindles of the automatic rotate at a speed which is constant for the given setup. The spindles are not reversed during the cycle. For this reason, a tool spindle is used in drilling holes of small diameter. Tool spindle *6* (see Fig. 102) is mounted in a travelling holder on the main tool slide. Tool spindles are driven from the gearbox through long spline shafts.

Tool spindles installed in the sixth and fifth positions may have independent feed (see Fig. 100), i.e., independent of the main tool slide. The roll of sector *2* (Fig. 105) is in constant contact with the profile of the work cam. The sector swivels on a stationary pin and transmits motion through adjustable link, or tie-rod, *3* to lever *4* which, in turn, is linked by tie-rod *5* to the travelling holder *1* carrying the tool spindle. The travel of this spindle is varied by adjusting tie-rod *3* along the slot of sector *2*.

Threads can be cut either with self-opening die heads and self-collapsing taps or with solid dies and taps but employing the "overrunning" method. Self-opening die heads and self-collapsing taps are mounted on tool spindles whose feed is effected with a special threading cam set up in place of the feed cam. When the thread has been cut to the required length, a stop trips the tool which opens or collapses and then is rapidly returned to the initial position.

The overrunning method, when used to cut right-hand threads, consists in rotating the tool spindle in the same direction as the work spindle but at a slower speed. The tool is advanced to the work by the starting cam. The lead of the tap or die then draws the tool spindle to follow the thread so that the tap screws into or the die screws onto the work. When the tap or die reaches the required length of thread, a clutch is automatically thrown to change the speed of tool rotation which is increased above that of the work spindle. As a result the tap or die is withdrawn from the work. Thus, thread cutting by the overrunning method requires that the tool spindle have two speeds of rotation: fast and slow. This is accomplished by automatically shifting a jaw clutch in the drive gear train of the tool spindle.

The automatic is equipped with a screw-type chip conveyer for chip disposal. It is arranged in the base and has a separate drive.

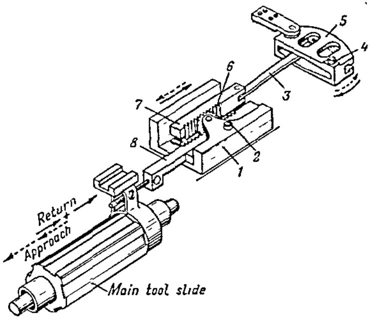


Fig. 104. Main slide drive in the model 1240-6 automatic

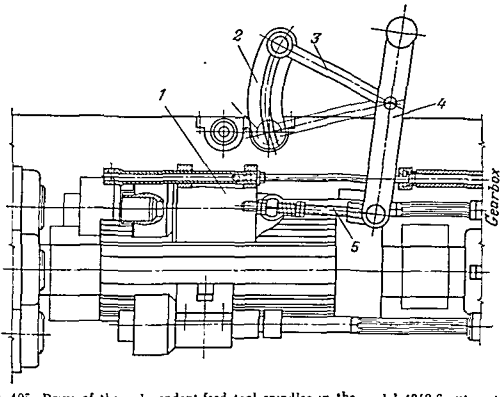


Fig. 105. Drive of the independent-feed tool spindles in the model 1240-6 automatic

4-5. Single-Spindle Semiautomatic Lathes

Depending upon the method for clamping the work semiautomatic lathes are classified as centre and chucking types.

Centre-type semiautomatics are employed to machine long blanks (for example, long stepped shafts) which are held between the headstock and tailstock centres. Short blanks of large diameter can be more conveniently held in a chuck on the chucking type of machine.

This classification is conventional, however, in that a chuck may sometimes be installed on the centre-type machines, and a tailstock with a centre, on the chucking type.

Most single-spindle semiautomatics are of the horizontal type.

Work of complex shape can be turned by several single-point tool simultaneously (Fig. 106) or by one single-point tool mounted on a tracer-controlled slide and operating to a template (Fig. 107). According to this feature semiautomatics can be classified as multiple-tool and tracer-controlled types.

Parts with a central hole can be efficiently machined in a semiautomatic turret lathe having a saddle with a multiple-face turret.

The automaticity of the working cycle of a semiautomatic may be based either upon mechanical or hydraulic systems.

Provision is made in the designs of up-to-date semiautomatic lathes for equipping them with automatic work loading and unloading devices, thereby converting them into machine tools with a fully automatic cycle, i.e., into automatics.

The principal dimensions of single-spindle semiautomatic lathes are the maximum diameter of workpiece accommodated over the carriage and the maximum length of workpiece admitted between the centres.

Figure 108 illustrates the single-spindle semiautomatic lathe, model 1730, whose automaticity is achieved by mechanical means. It is intended for turning blanks between centres with high-speed steel or carbide-tipped single-point tools. The general arrangement of the units is the same as for an ordinary lathe. Bed *2*, mounted on base *1*, carries headstock *5* and tailstock *3*. Front carriage *4* travels longitudinally along the bed ways. The rear carriage feeds crosswise and is employed for facing, cutting off, grooving, etc. Figure 109 shows the gearing diagram of the semiautomatic lathe.

The spindle is powered from a 10-kW motor, running at 1,455 rpm, through V-belts, change gears $\frac{a}{b}$ and bevel gears $\frac{18}{80}$. Change gears a and b serve to set up the speed of the main drive.

Working feed of the front carriage (longitudinal feed s_l) is accomplished through the following gear train: spindle, gears $\frac{76}{76} \times \frac{22}{68} \times \frac{68}{73}$, change

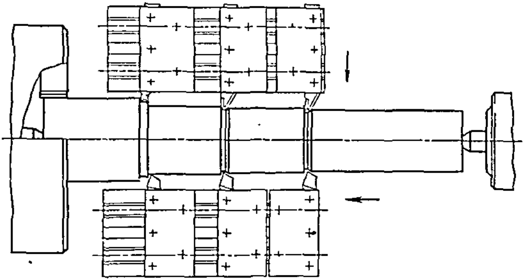


Fig. 106. Multiple-tool turning operation

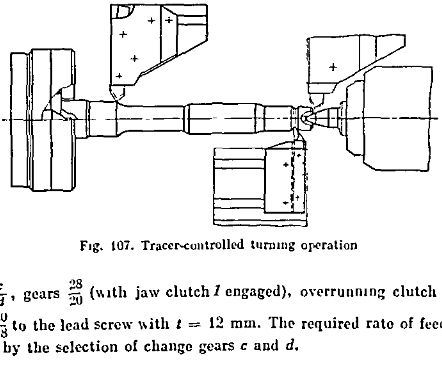


Fig. 107. Tracer-controlled turning operation

gears $\frac{c}{d}$, gears $\frac{28}{20}$ (with jaw clutch *1* engaged), overrunning clutch *2*, and gears $\frac{20}{78}$ to the lead screw with $t = 12$ mm. The required rate of feed is obtained by the selection of change gears c and d.

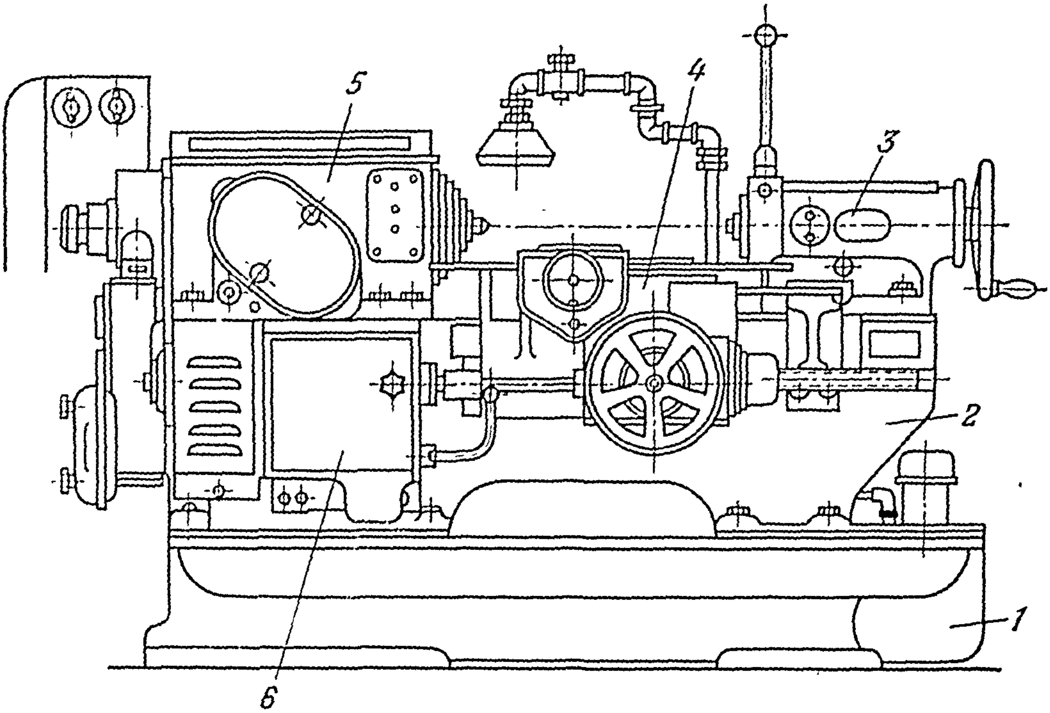


Fig. 108. Single-spindle semiautomatic lathe, model 1730

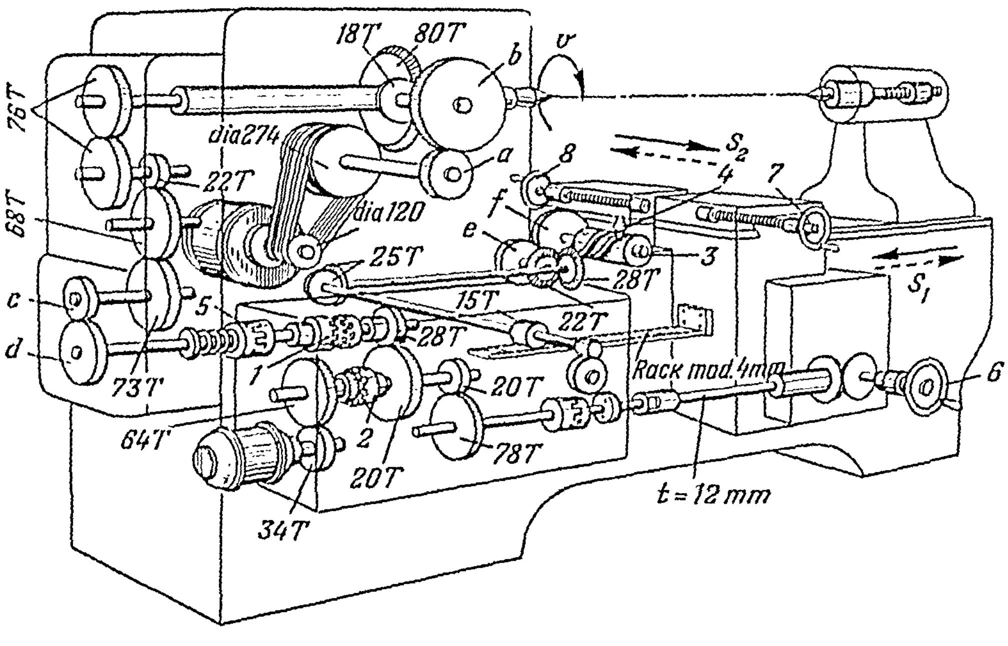


Fig. 109. Gearing diagram of the model 1730 semiautomatic lathe

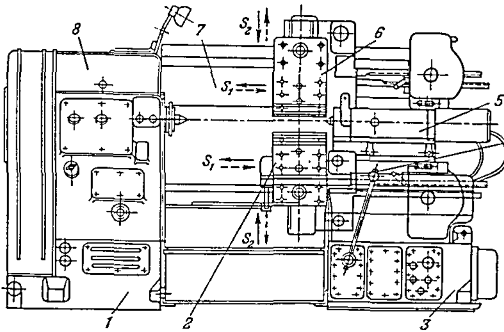


Fig. 110. Hydraulic multiple-tool semiautomatic centre-type lathe

The rear (cross-feed) carriage has feed motion only upon the feed of the front carriage from which it is driven. A gear rack with a module of 4 mm, fastened to the front carriage, rotates a pinion with 15 teeth. Power is transmitted further through gears $\frac{25}{25} \times \frac{28}{22}$, and change gears $\frac{e}{f}$ to cylinder cam *3*. Roll *4*, secured to the rear carriage, enters the helical slot of cam *3*. Change gears *e* and *f* can be selected to obtain the required cross feed (s_2).

Rapid traverse movements of both carriages are powered by a separate 1-kW motor running at 1,450 rpm. The provision of overrunning clutch *2* permits rapid rotation to be transmitted through gears $\frac{34}{64}$, overrunning clutch *2* and gears $\frac{20}{78}$ without disengaging clutch *1*.

Safety clutch *5* protects the mechanisms against overloads. The carriages can be traversed manually by turning handwheels *6*, *7* and *8* in setting up the semiautomatic.

The automatic operating cycle of the lathe consists of rapid approach, working feed, rapid return of the carriages to the initial position and stop-

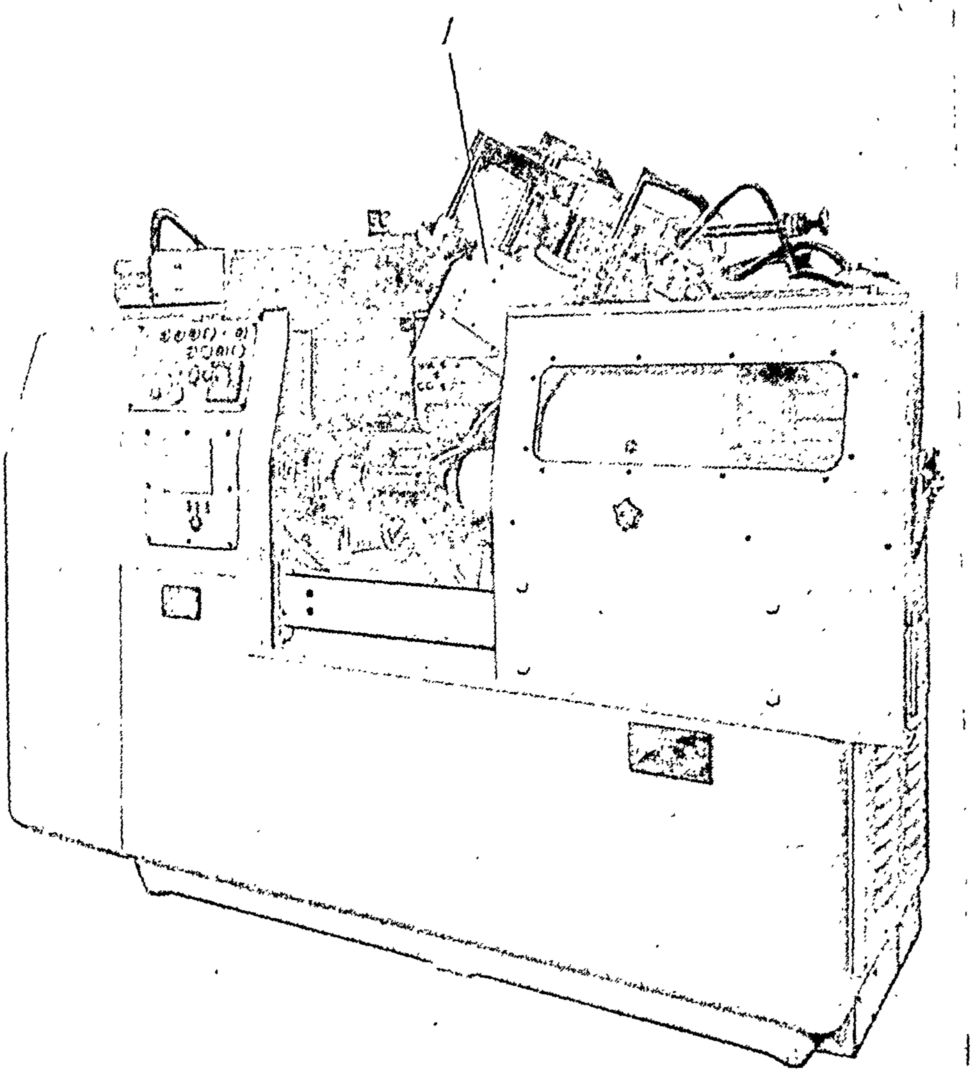


Fig. 111. Hydraulic tracer-controlled semiautomatic centre-type lathe, model 1708

ping of the work spindle. After this the operator removes the finished workpiece, loads a new blank and starts the lathe again.

The automatic cycle is controlled by the special electric control system housed in cabinet *6* (see Fig. 108) which is arranged conveniently at the front of the lathe.

The lengths of travel at working feed and rapid traverse are set up for both carriages by setting trip dogs on a rack in the control system.

Two models of single-spindle semiautomatic lathes of this type are manufactured at present in the USSR; their principal dimensional data are listed in Table 13.

TABLE 13

Model	Maximum workpiece diameter over carriage × × maximum length of workpiece, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.
1M720	200×320	146 to 1,400	7.5	2,000
1Б713	320×500	100 to 1,000	13	3,700

Single-spindle semiautomatic lathes whose automaticity is based on a hydraulic system have found extensive application in recent years. The use of a hydraulic system in the feed drive facilitates automation of the cycle and simplifies setting up, substantially reducing the setting-up time. The hydraulic semiautomatic lathes produced in the Soviet Union include both multiple-tool and tracer-controlled models.

The general view of a hydraulic multiple-tool semiautomatic centre-type lathe is shown in Fig. 110. Bed *7*, which carries the principal units of the lathe, is mounted on legs *1* and *3*. Mounted at the left on the bed is the headstock *8* with the speed gearbox which imparts 14 different speeds to the spindle. Speeds are changed by means of two sliding double cluster gears and change gears.

Tailstock *5* with a running centre is mounted at the right on separate ways of the bed. The tailstock spindle is actuated by a hydraulic cylinder. Tailstock spindle travel is controlled from the lever with head *4*.

Upper *6* and lower *2* tool slide carriages are traversed along the inclined ways (15° from the vertical) of the bed by hydraulic cylinders mounted at the left end. Each carriage has longitudinal working feed (s_1) and rapid traverse movements, cross feed (s_2), and angular and straight infeeds. The tool relief mechanism withdraws the tools rapidly from the work at the completion of a cut so as not to mar the machined surface when the tools return to their initial position

Tracer-controlled semiautomatic centre-type lathes (Fig 111) differ from the multiple-tool models in that they have a tracer-controlled tool slide *1* by means of which a workpiece of complex shape can be turned with a single point tool to a template or master mounted on the lathe Facing and grooving operations are performed by one or two lower slides which are fed in with a rocking motion. The operation of the hydraulic system of these semiautomatics is considered in detail in Vol. IV. Part Six.

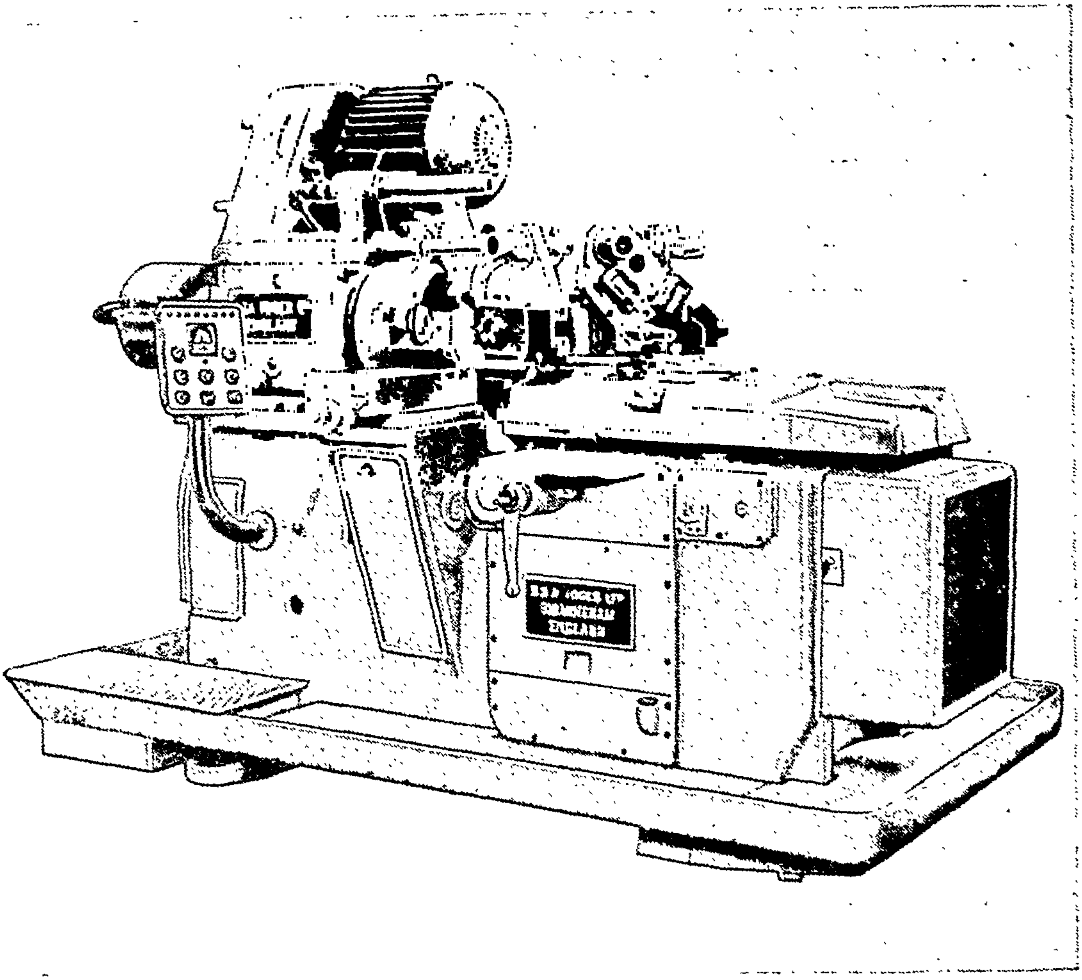


Fig. 112. Single-spindle semiautomatic turret lathe, model BSA95 (BSA Tools Ltd., England)

TABLE 14

Model	Maximum workpiece diameter × maximum length of workpiece, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.
1708	200×500	200 to 2,000 or 400 to 3,200	10	3,600
1713	250×710	100 to 1,600 or 250 to 2,500	17 to 22	4,600
1719	320×1,000	63 to 1,250	30 to 40	6,500
	320×1,400			6,800
	320×2,000			7,200

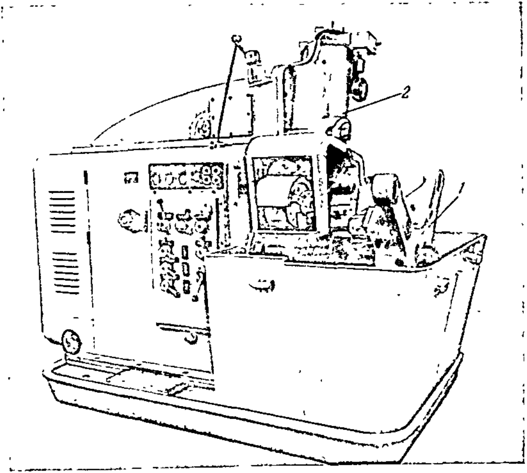


Fig. 113. Single-spindle semiautomatic chucking machine, model 1425

Table 14 lists the principal dimensional data on hydraulic semiautomatics made in the Soviet Union.

Semiautomatic turret lathes, commonly called single-spindle semiautomatic chucking machines, are designed for machining work having a central hole. Available models of such semiautomatics differ in the layout of the principal units and in the method by which the working cycle is automated.

A semiautomatic lathe (called an automatic chucking machine by its manufacturer) with an arrangement similar to the ordinary turret lathe with a vertical axis of turret indexing is shown in Fig. 112. All working and aux-

iliary motions are obtained with the aid of an interchangeable programm
disk through electrical controls.

In the single-spindle semiautomatic chucking machine, model 1425 the cross-type turret (with four tooling stations) is mounted on a longitudi nal turret bar secured in the headstock and indexed about a horizonta axis parallel to the spindle axis (Fig. 113). The working feed (s_1) and rapid traverse of longitudinal slide *1* of the turret and the working feed (s_2) and rapid traverse of the cross slides *2* are actuated by the hydraulic system. Built-in friction clutches in the speed gearbox change the spindle speed when the turret is indexed.

Turret indexing, speed and feed changing, and chuck action are all hydraulically operated. Work up to 250 mm in diameter can be accommodated in the model 1425 semiautomatic. Spindle speeds range from 63 to 2,000 rpm; the drive motor rating is 7 kW; the machine weighs approximately 3,500 kg.

4-6. Semiautomatic Multiple-Spindle Ve.tical Chucking Machines

Multiple-spindle vertical semiautomatics are designed for the mass production of parts of comparatively large size from blanks held in chucks or, much less frequently, between centres. Such machines are widely employed in the automobile and tractor industries. They are classified according to their principle of operation into multiple-station progressive-action and continuous types.

Up-to-date semiautomatics of both types are available with four to twelve spindles. The vertical arrangement offers the following advantages: it is much more convenient to load the blanks and unload the finished work, and the spindles are relieved of an additional bending load due to the weight of the workpiece.

The principal dimension of both types of semiautomatics is the maximum liameter of workpiece accommodated in the machine.

In the multiple-spindle vertical progressive-action semiautomatics Fig. 114) the spindles, in the chucks of which the blanks are clamped, ndex consecutively from station to station. In each station (position) one several machining operations are performed on the blank in accordance th the setup. One is the loading station. The work is loaded and unloaded th the spindle stationary. As a rule, a finished workpiece is produced in e spindle carrier cycle around the central column. Since all the stations working simultaneously on the different operations of the same workce, each spindle delivers a finished workpiece as it is indexed to the load- station.

Castings and forgings of various types are machined in vertical semiautomatics. The most common operations are turning and facing, boring, recessing, core drilling and reaming. Thread cutting is much less frequent.

Until recently, progressive-action multiple-spindle vertical semiautomatics, produced in the USSR and other countries, had automatic features based on mechanical means (Fig. 115).

On base *1* of the machine are mounted spindle carrier *2* (enclosed by shields in the figure) with rotating spindles *3* (primary cutting motion v) and stationary column *7* having as many faces as there are spindles. With the exception of the face at the loading station, guides are secured to the column faces on which the tool-carrying heads *6* travel. These heads have longitudinal (s_1), cross (s_2) or compound (s_1, s_2) working feeds, as well as rapid approach and withdrawal. The machine is driven by motor *4*, mounted on the top of the column, through a central shaft which controls all the movements of the machine.

At each station the spindle rotates at a speed and the tool heads travel at a feed that are set up beforehand to suit the machining operations being performed at the given station. Spindle rotation is disengaged at the loading station.

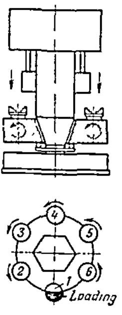


Fig. 114. Principle of the semiautomatic multiple-spindle vertical progressive-action chucking machine

The spindle carrier is indexed by a link gear controlled by the central shaft. Feed works base *5* is mounted on the column and houses the speed and feed gearboxes.

New features of the latest models of progressive-type multiple-spindle vertical semiautomatics include electrohydraulic controls by means of electric control units, and hydraulic clamping facilities.

At each station the tool heads have two different rates of feed, high and low, in the course of the cycle, as well as rapid approach and withdrawal. The spindles have two series of speeds. Tool head travel is effected by a screw and nut; feeds are controlled by electric control units. The spindle carrier is indexed by a Geneva motion. The design provides for the possibility of automatic loading and for building the machine into a transfer machine.

Brief specifications of multiple-spindle vertical progressive-action semiautomatics produced in the Soviet Union are given in Table 15.

In the multiple-spindle vertical semiautomatic lathes of the continuous type (Fig. 116) the spindle carrier and multiple-face outer column with the tool heads are an integral whole and rotate continuously about the station-

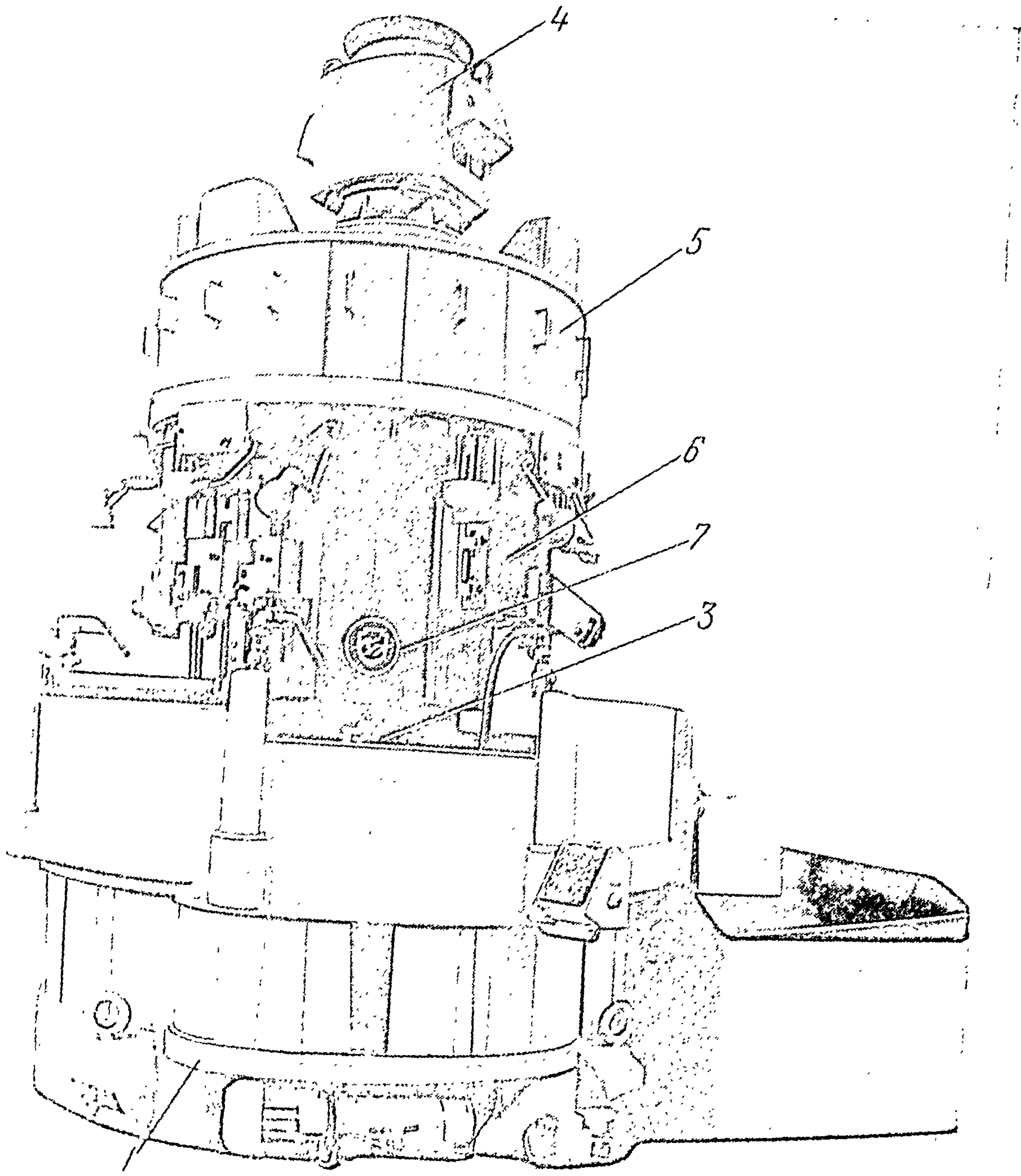


Fig. 115. Semiautomatic multiple spindle vertical progressive-action chucking machine model 1283

TABLE 15

Model	Maximum diameter of surface turned, mm	Number of spindles	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.
1K282	250	8	42 to 980	22 to 55	17,500
1283C	250	16	42 to 980	22 to 100	19,500
1283	400	8	43 to 635	22 to 100	19,900
1284	400	6	21 to 184	22	14,500
1286-8	500	8	32 to 500	40 to 100	32,000
1286-6	630	6	25 to 400	40 to 100	35,000
1286-4	800	4	20 to 315	100	42,000

ary inner column. Thus each spindle has its own tool head from which the machining operations are performed. The operating cycle is planned so that a workpiece is finished in each spindle in the time it takes the carrier and outer column to make one full revolution. Thus machining is completed as the spindle enters the loading zone. Here spindle rotation is first automatically disengaged, the work is released in the clamping facilities and the corresponding tool head is rapidly withdrawn to its upper position. Next, the operator removes the finished workpiece and loads a new blank. This is followed by automatic clamping of the blank, the spindle starts to rotate again and the tool head rapidly approaches the blank.

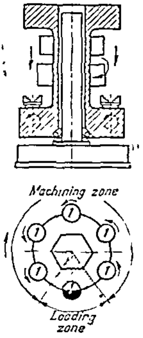


Fig. 116. Principle of the semiautomatic *multiple-spindle vertical* continuous-type chucking machine

If this machine is equipped with an automatic loading and unloading device it becomes a fully automatic machine tool.

Figure 117 illustrates the gearing diagram of the six-spindle continuous-type vertical semiautomatic, model 1285.

Central stationary inner column *7* is mounted on base *1*. Column *7* serves as a pivot about which the spindle carrier with work spindles *9* and the hexagonal outer column *8* with tool heads *3* rotate. The spindles (main cutting motion *v*) are powered from motor *2* through a gear train. Spindle speeds, constant for each setup, are obtained by selecting the required change gears *A* and *B*.

The outer column and carrier are rotated by a drive from a separate motor *10* through reducing gear *11*. The last element in this gear train is a worm

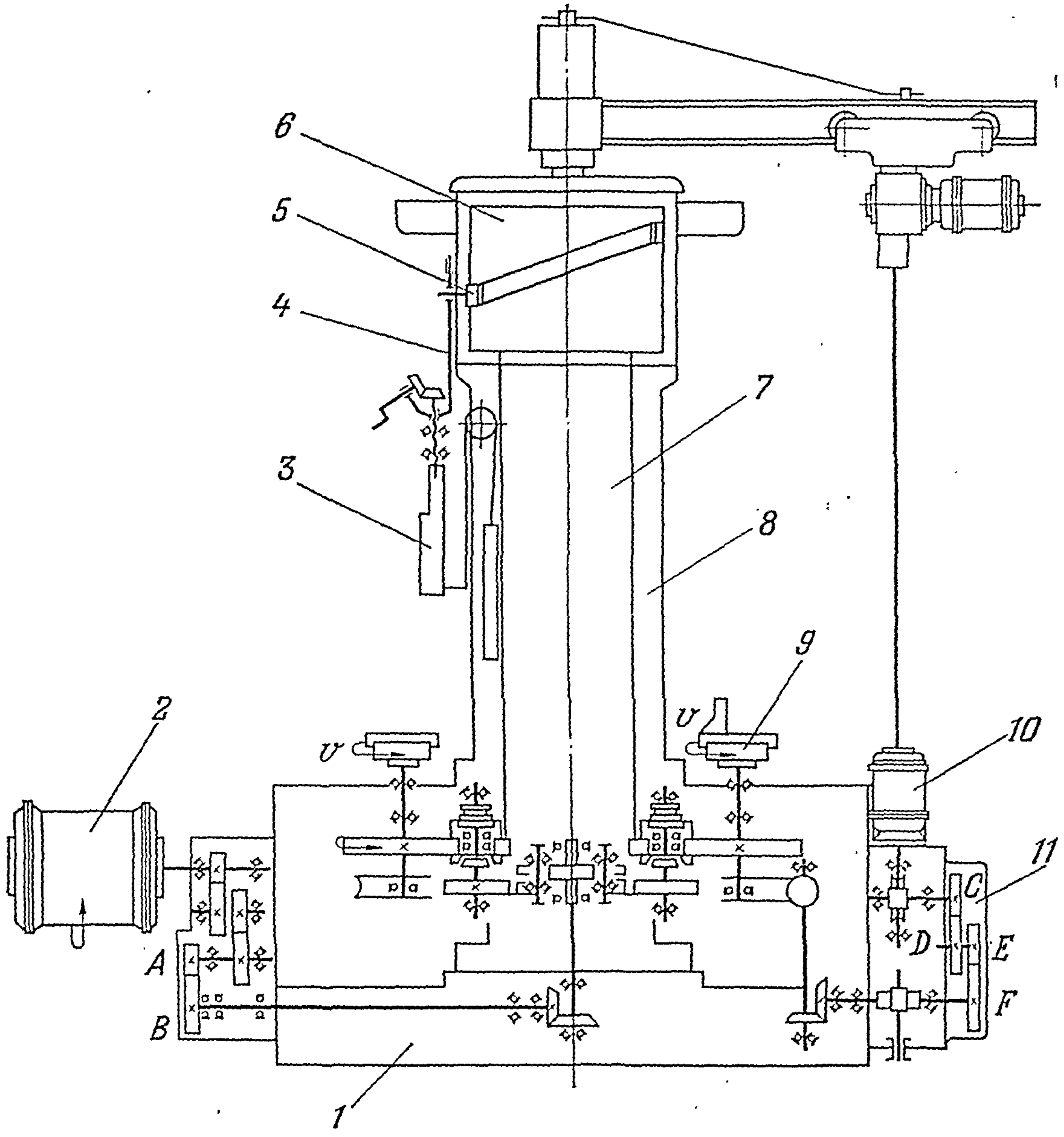


Fig. 117. Gearing diagram of the model 1285 vertical semiautomatic

gearing arrangement. Change gears C, D, E and F are used to set up the speed of rotation of the carrier, i.e., the cycle time.

The tool heads are operated from the constant cams of a stationary drum 6. Through roll 5 and tie-rod 4, motion is transmitted to the tool slide of each

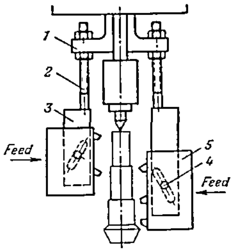


Fig. 118. Operation of a parallel-action tool with horizontal feed

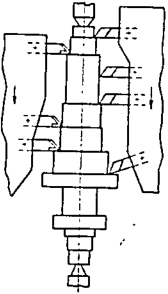


Fig. 119. Tooling layout for a stepped shaft on a continuous-type vertical semiautomatic

head travelling on guides of the stationary member secured to the face of the outer column.

The initial position of the tool slide is set up by hand using the bevel gearing, screw and nut. Available tool heads include the standard plain type for vertical feed (s_1) and rapid traverse only, and the parallel-action compound type for either vertical or horizontal (s_2) feed.

The principle of operation of a parallel-action tool head for horizontal feed is shown in Fig. 118. Bracket *1* with its adjustable tie-rods *2* is actuated by the feed drum cams. The tie-rods move plates *3* which have inclined slots for rolls *4*. The rolls are secured in tool slides *5* carrying the cutting tools. Thus, when the plate is moved up or down the tool slides travel horizontally to the right or left. Since the cams are constant on the drum, the rate of working feed or rapid traverse depends upon the speed of rotation of the carrier and column, i.e., upon the set-up cycle time.

The tooling layout for a stepped shaft, produced in a continuous-type vertical semiautomatic, is shown in Fig. 119.

The new hydraulic six-spindle vertical semiautomatic lathe, model 1272, can operate with either a semiautomatic or an automatic cycle. In the latter

TABLE 16

Model	Maximum diameter of surface turned, mm	Number of spindles	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.
1A272	250	6	Up to 1,250	7.5 to 13 (each spindle)	17,000
1273	320	6	Up to 1,000	10 to 17 (each spindle)	19,000
1275	500	6	Up to 630	Up to 100	26,000

case, the blank is loaded and the finished workpiece is unloaded by a loading attachment (automatic handling device). This model has longitudinal carriages and cross-feeding slides which considerably extend its processing capacities. The carriages and slides are hydraulically operated and the cycle is controlled by a tracer system. This principle enables loading and unloading to be carried out with the carrier in a fixed position though machining continues on the other spindles. This simplifies the construction of the automatic handling device and makes its operation more reliable.

The operation of the hydraulic tool slides is taken up in detail in Vol. IV, Part Six. Table 16 lists brief specifications of the multiple-spindle continuous-type vertical semiautomatics manufactured in the USSR.

CHAPTER 5
DRILLING MACHINES

5-1. Purpose and Field of Application of Drilling Machines

Drilling machines are designed for producing through and blind holes in solid material, for finishing (core drilling and reaming) rough holes made in the blank by drilling or other methods, as well as for tapping threads, counterboring, countersinking and spotfacing.

Employing special tools and attachments, drilling machines can be used to bore holes, cut out large holes in sheet metal by trepanning, lap precise holes and perform other operations.

Drilling machines find application in machine, assembly and repair shops, and in toolrooms of engineering plants, as well as in maintenance departments servicing transportation facilities, building and agricultural machinery.

Holes are machined in drilling machines with twist drills, core drills, reamers, countersinks, counterbores, spotfacers and other tools; threads are cut with taps.

The following types of general-purpose drilling machines are available: (1) bench-type drill presses (single-spindle); (2) upright drill presses (single-spindle); (3) radial drills; (4) gang drills; and (5) deep-hole-drilling (horizontal-drilling) machines.

Most widely used in the general engineering industries are the upright drill press and the radial drill.

The principal dimensions of a drilling machine are the drilling capacity in steel of medium hardness with a tensile strength of $\sigma_b = 50$ to 60 kg per sq mm, the size of the taper in the spindle socket, the distance from the spindle centre to the face of the column (overhang), and the distances from the spindle nose to the table and to the base

5-2. Upright Drill Presses

Brief specifications of up-to-date Soviet upright drill presses are given in Table 17.

The primary cutting motion v of these machines is the rotation of the spindle which holds the cutting tool, while the feed motion s_1 is the axial motion of the spindle (Fig. 120).

TABLE 17

Model	Drilling capacity in steel (tensile strength $\sigma_b = 50$ to 60 kg/mm²), mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.	Remarks
2Н103П	3	2,000 to 16,000	0.27	40	Bench-type
2Н106П	6	1,000 to 8,000	0.4	70	Bench-type
2Н112П	12	500 to 4,000	0.6	130	Bench-type
2Н118	18	180 to 2,800	1.5	450	Upright
2Н125	25	45 to 2,000	2.2	800	Upright
2Н135	35	31.5 to 1,400	4	1,300	Upright
2Н150	50	22.5 to 1,000	7.5	2,250	Upright
2Н175	75	18 to 800	10	3,500	Upright
2Н135Пр	35	35 to 1,400	4	1,700	Upright with numerical controls
2Р132Пр	35	35 to 1,400	4	1,900	Upright with numerical controls and turret
2Н175Г	75	18 to 800	10	3,700	Upright, turret-type

The workpiece is placed on the work table or directly on the base. The axis of the hole to be machined is aligned with the spindle axis by moving the workpiece along the table or base.

The principal units of an upright drill press (Fig. 120) are: column *2*, base *1*, speed gearbox *3*, spindle *5*, feed gearbox and feed mechanism *4*, and work table *6*.

The column is a hollow box-shape casting which is mounted rigidly on the base and carries all the other principal units. Vertical ways are provided on the front face of the column for the sliding spindle head and the table. The electric control devices and the spindle counterweight are housed in the cavity of the column.

The base is the footing which supports the whole machine. In medium and heavy-duty drill presses, heavy workpieces are placed on the top surface of the base. The cavities of the base serve as a reservoir for the cutting fluid.

The speed gearbox usually consists of sliding gears which are engaged in various combinations to obtain the different spindle speeds. The spindles of modern drill presses run at 6 to 12 different speeds obtained by a combi-

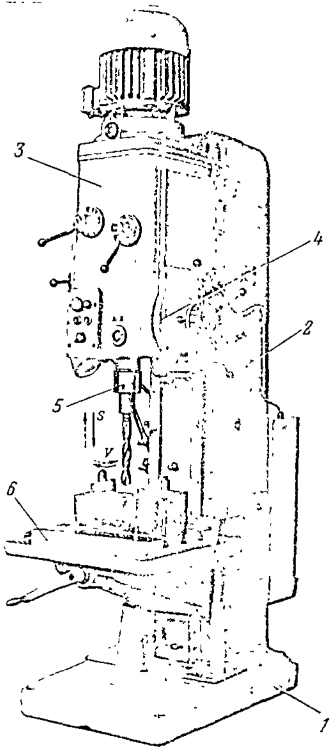


Fig. 120. Upright drill press, model 2H135A

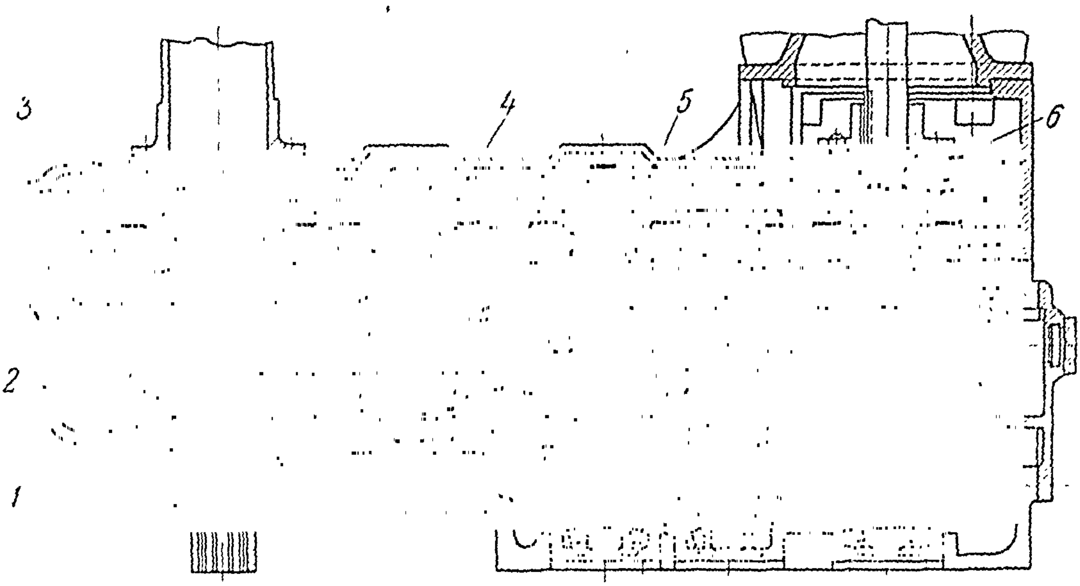


Fig. 121. Speed gearbox of an upright drill press

nation of a speed gearbox and a single- or two-speed drive motor. A stepless variable-speed drive has been used on certain models in place of the speed gearbox. The speed gearbox of an upright drill is shown in Fig. 121. Housing *1* is fastened to the top of the column. The drive motor is mounted on cover *3* of the gearbox; it is linked through flexible coupling *6* with the input shaft of the gearbox. Six different speeds are imparted to hollow shaft *2* (with a single-speed drive motor) by shifting two sliding cluster gears *7* and *8*. This hollow shaft has internal splines which transmit rotation to the spindle. Change gears *4* and *5* enable a higher range of spindle speeds to be obtained. This feature proves highly efficient in machining workpieces of nonferrous metals.

Spindle *1* (Fig. 122) has a spline shank which fits the spline hole in the hollow shaft of the speed gearbox and rotates together with this shaft. At the same time the spindle can travel in the axial direction to provide the feed motion. The cutting tool is held at the lower end of the spindle, either directly in the tapered socket, or in a sleeve or other attachment.

The considerable axial loads developed in drilling are taken up in light machines by angular-contact ball bearings; in medium and heavy-duty machines, ball or roller thrust bearings *3* are used for this purpose. These bearings are mounted in quill *2* which imparts the axial motion to the spindle and is traversed by a pinion-and-rack drive from the spindle feed mechanism.

The feed gearbox provides the range of spindle feeds required in machining with various tools. Depending upon the size of the machine the spindle may have from 4 to 12 different rates of feed. The feed gearbox is powered directly from the spindle or from a shaft of the speed gearbox linked to the spindle through a constant transmission.

In existing constructions of feed gearboxes the required spindle feed is obtained by shifting sliding cluster gears, by engaging and disengaging clutches in various combinations, or by gear cones and a sliding key. The feed *gearbox is located, as a rule, in the sliding spindle head.*

The feed mechanism in upright drill presses provides for power and hand feeds of the spindle. When power feeds are engaged a clutch links the output shaft of the feed gearbox to the spindle quill. When manual feed is engaged, rotation is transmitted directly from the handwheel or pilot wheel to the pinion which meshes with the rack of the spindle quill bypassing the power feed gear train. The mechanism is equipped with a device for automatically disengaging power feed when the preset depth of machining is reached.

The table of the drill press is the unit on which the workpiece is clamped. It can be adjusted vertically along the column in most models, and can be swung out of the way in machines with a round column to enable heavy work to be placed directly on the base. The table is mounted on the column ways (box column), on the column itself (round column) or it is of box shape and is mounted on the base.

The table of models designed for lot production can be traversed with the clamped workpiece in the longitudinal and transverse directions (compound table). This construc*tion permits a series of holes to be machined without* setting up and clamping the work for each hole.

Special programme-controlled tables (sometimes called spacers) are available for drilling a series of holes in a workpiece without resorting to a jig. First the co-ordinate dimensions of the holes are set up and then the table and

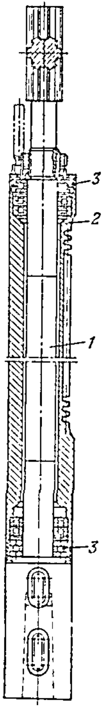


Fig. 122 Spindle of an upright drill press

saddle are automatically positioned for each hole in a definite sequence. This procedure is repeated for each workpiece of the lot. The accuracy with which the holes are positioned under the spindle is approximately that achieved when a jig is used.

A considerable part of the handling time in hole-making operations is spent in changing the cutting tools. The use of a quick-change chuck, enabling tools to be changed without stopping the spindle, substantially reduces this handling time. The degree of automaticity of the machine, however, is not increased since tool changing is still done by hand.

The degree of automaticity can be increased if the upright drill press is equipped with a special turret which is indexed and locked automatically. In this case, automatic control of the spindle speeds and feeds is also required. Promising in this line is the new upright drill press, model 2Б135, designed in the ENIMS Institute. The speed gearbox of this machine is equipped with noncontact electromagnetic clutches which automatically change spindle speeds. In place of the ordinary step-type feed gearbox, a magnetic-particle clutch is incorporated in the feed gear train, enabling spindle feeds to be automatically controlled in a stepless range. An overrunning mechanism is provided in the feed gear train for hand traverse of the spindle.

A drill press of this type can be readily built into an automatic transfer machine or automated production line.

5-3. Radial Drills

Radial drills are intended for machining large heavy work with a great number of cutting tools in piece and lot production. They differ from the upright drill press in that the spindle axis is made to coincide with the axis of the hole being machined by moving the spindle in a system of polar co-ordinates to the hole while the work is stationary. The layout of the principal units (Fig. 123) is such that the spindle with the tool can be easily moved to any point within the working zone by traversing drill head *5* along the ways of arm *4* and swivelling the arm about column *2*.

Brief specifications of radial drills manufactured in the Soviet Union at the present time are listed in Table 18.

Models 2H53, 2H55, 2M57 and 2M58 are general-purpose radial drills. In some models the arm has no vertical movement on the column. They can be efficiently used for drilling comparatively low work of large area or plates. Models 2Ш55 and 2Ш57 are of the portable type and intended for machining holes in very large workpieces. These portable radials are carried to the place of work by a crane. They have swivelling arms and heads and can drill vertical, horizontal and inclined holes.

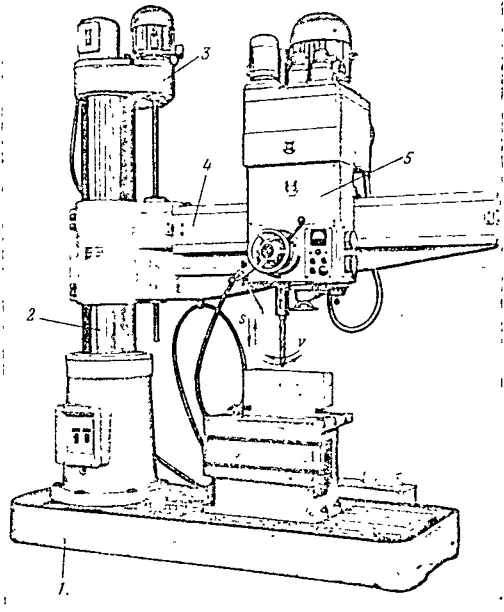


Fig. 123. Radial drill, model 2H55

TABLE 18

Model	Drilling capacity in steel (tensile strength $\sigma_b = 50$ to 60 kg/mm^2), mm	Distance, spindle to column, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.	Remarks
2H53	35	1,250	40 to 2,500	2.2	3,000	
2H55	50	1,600	20 to 2,000	4	4,000	
2H55Пр	50	1,600	20 to 2,000	4	4,000	With numerical controls
2M57	75	2,000	12.5 to 1,600	7.5	10,000	
2M58	100	3,150	10 to 1,250	13	18,000	
2Ш55	50	1,600	10 to 1,000	4	7,000	With swivelling spindle head
2Ш57	75	2,250	6.25 to 800	7.5	17,500	Ditto

Self-propelled radial drills, frequently employed in bridge building, have the drill mounted on a self-propelled truck which travels along railway tracks. They are rigidly clamped for operation at the required site by means of hydraulic clamping shoes which grasp the rails.

The primary cutting motion v in a radial drill (Fig. 123) is spindle rotation, while the feed motion s is the axial feed of the spindle with the quill.

Auxiliary motions include swivelling of the arm and clamping it on the column, vertical traverse of the arm and its clamping at the required height on the column, traversing of the spindle head and its clamping along the arm, changing spindle speeds and feeds, etc.

The principal units of a radial drill (Fig. 123) are column *2*, base *1*, arm *4*, arm elevating and clamping mechanism *3*, and drill head *5*.

The column (Fig. 124) consists of two parts: stationary inner column *1* secured rigidly to the base, and rotary outer column *2*. The outer column is clamped in the required position by yoke *6* which encircles the tapered surfaces on the flanges of the two columns. The yoke is contracted to clamp the column by bolts *5* which are fitted on the eccentric journals of shaft *4*. When the shaft is turned, bolts *5* are either pulled together or spread apart, thereby clamping or releasing the column. When the clamping yoke is released, disk (Belleville) springs *3* relieve the bearing surfaces at *A* of pressure due to the weight of the parts being swivelled so that the outer column and arm can be easily swivelled about the inner column.

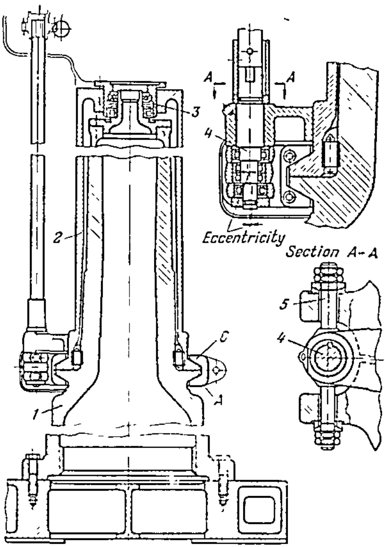


Fig. 124. Column of a radial drill

In the latest Soviet models, eccentric shaft 4 is turned by a hydraulic device.

The base and traverse are grey iron castings stiffened by internal ribbing. The arm has horizontal ways along which the drill head travels

The arm elevating and clamping mechanism provides for rapid vertical traverse of the arm along the outer column and rigid clamping in the required position. Clamping and unclamping of the arm are automatically inter-

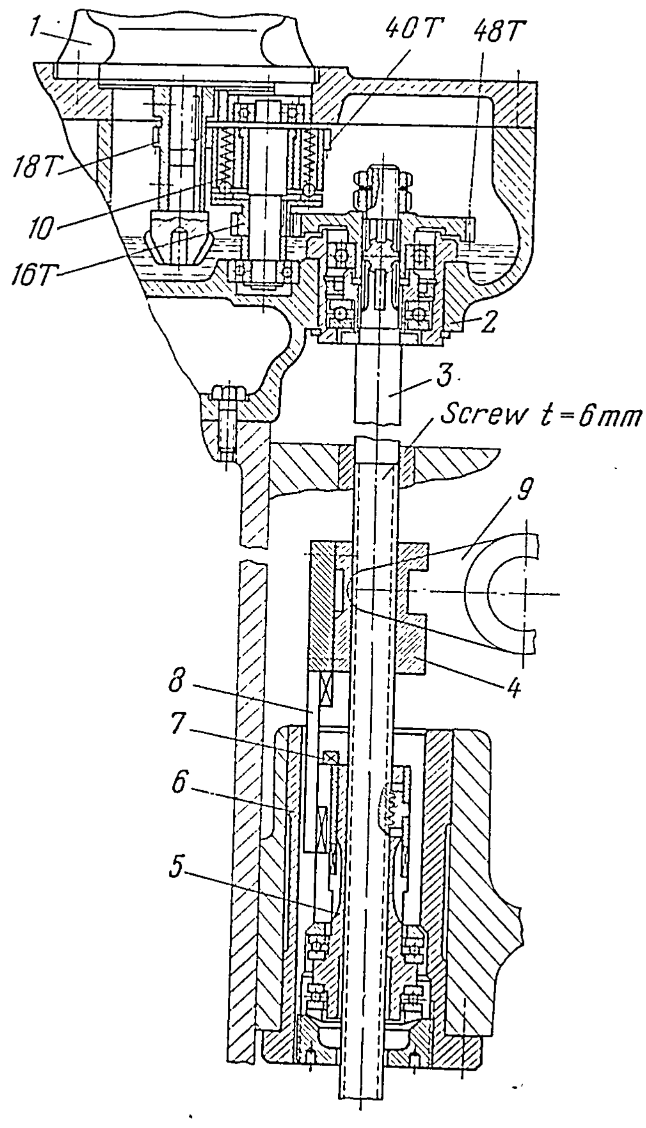


Fig. 125. Arm elevating mechanism of a radial drill

locked with arm traverse along the column. From motor *1* (Fig. 125) powe is transmitted through reducing gear *2* to vertical screw *3*. Ball-type safet clutch *10* protects the motor and the mechanism against overloads.

Nut *5*, located in a bore of the arm, rotates together with screw *3* whe the mechanism begins to operate. At this stage auxiliary nut *4* travels alon

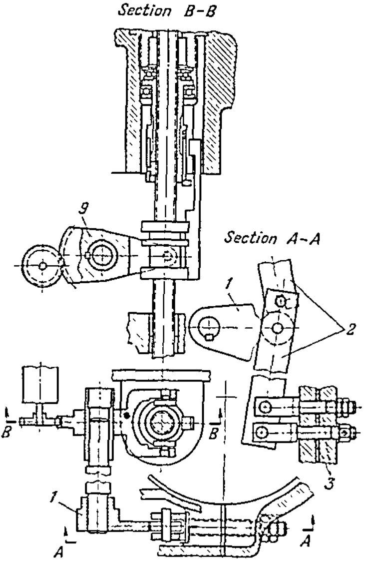


Fig. 126. Arm clamping mechanism of a radial drill

screw *3* since it is held against rotation by key *8* sliding along the keyway of fixed sleeve *6*. The movement of nut *4* turns lever *9* which releases the clamp binding the arm on the column.

As lever *9* rotates, it turns cam *1* (Fig. 126) which, by means of lever *2* and bolts *3*, releases the arm. At this same moment, depending upon the

direction of rotation of screw *3*, one of the lugs of key *8* (Fig. 125) approaches lug *7* of nut *5*. This stops the rotation of the nut and the arm begins to travel up or down. At the end of arm travel, motor *1* is reversed instead of being switched off. At this, the arm stops (the lug of key *8* moves away from lug *7*) and nut *4* begins to travel in the opposite direction. This again turns lever *9* thereby clamping the arm. Motor *1* is stopped at the same time by a special switch.

The drill head of a radial drill is a self-contained unit combining the speed and feed gearboxes, feed mechanism, spindle, and head traverse and clamping mechanism.

The drill head of the model 2A53 radial drill can be considered in more detail as an example. The speed gearbox (Fig. 127) is arranged in the upper part of the head and transmits 12 reversible speeds in a range from 50 to 2,240 rpm to spindle *6*. The gearbox is powered from a two-speed motor *1* (1,420 and 2,840 rpm). Power is transmitted through gears $\frac{21}{33}$ to a twin multiple-disk friction clutch *2* operated by fork *5*. The two engagements of the clutch and the two speeds of the motor impart four different speeds to shaft *IV*, the gear train being either through gears $\frac{36}{39}$, or through gearing $\frac{28}{28} \times \frac{28}{42}$, the direction of rotation of shaft *IV* being changed by the inclusion of the intermediate gear. Shaft *VI* is a cast-iron sleeve with internal splines, the spline shank of the spindle fitting and sliding in this spline hole. Shaft (sleeve) *VI* carries the sliding double cluster gear, $29T$, and $51T$, which can be shifted to either of three positions. In the first position the smaller gear ($29T$) of the cluster meshes with gear $39T$ of shaft *IV*; in the second position the larger gear ($51T$) meshes with gear $17T$ of shaft *IV*. Thus the eight upper speeds of the series are obtained. The drive motor is automatically reversed when clutch *2* is shifted so as to retain the direction of spindle rotation. In the third position of the sliding cluster gear, the larger gear ($51T$) meshes with gear $17T$ of shaft *V* (countergearing) which is driven by shaft *IV* through gears $\frac{15}{60}$. This provides the four lower speeds of the series. Here also the motor reverses automatically whenever necessary to retain the direction of spindle rotation.

Rim *4* in the lower part of clutch *2* is encircled by brake *3* which stops the spindle when fork *5* is shifted to the middle (neutral) position.

The speed gearbox is equipped with a speed-changing mechanism (Fig. 128) which allows the spindle speed required for the next operation to be preselected in the course of the current operation.

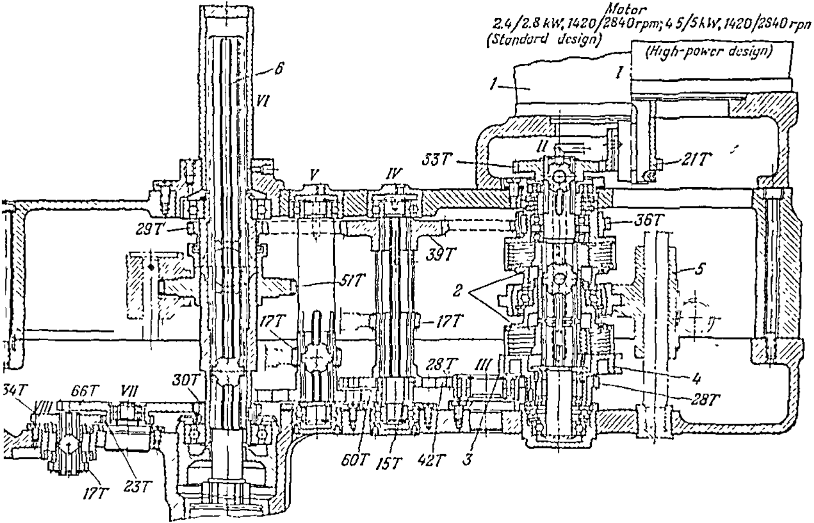


Fig. 127. Speed gearbox of the model 2A53 radial drill

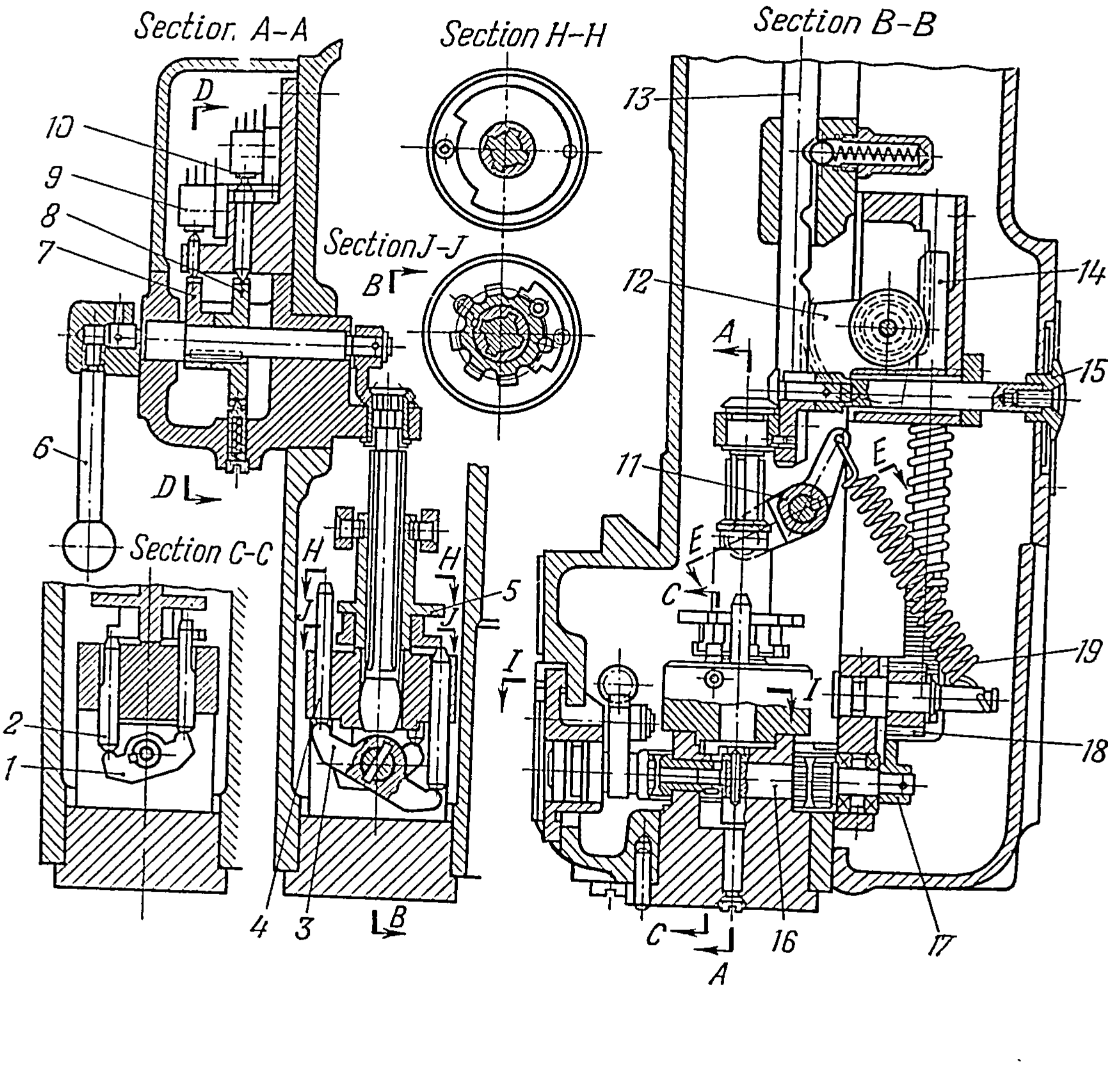
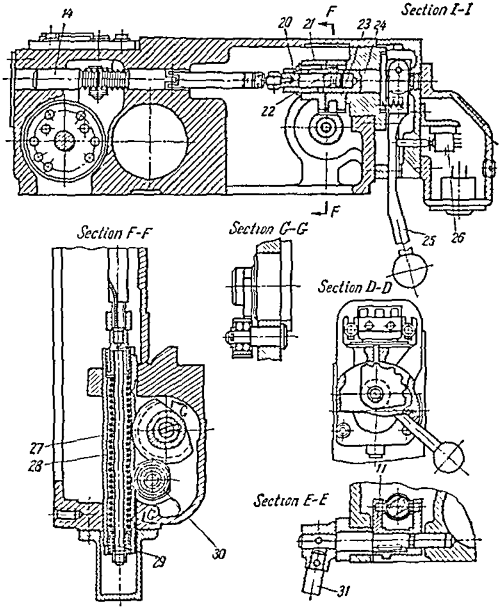


Fig. 128. Speed-changing mechanism of the model 2A53 radial drill

This preselected speed is then engaged, after the spindle is stopped, simply by shifting a single lever.

The main element of this mechanism is double-disk member *5* in which the disks have holes arranged in a definite order. Opposite these disks are



push-rods *2* and *4* which are interlocked in pairs. Push-rods *4* actuate lever *3* which is linked through parts *16*, *17*, *18*, *19*, *14* and *12* with rod *13*. This rod carries the fork which shifts the sliding double cluster gear, 29*T* and 51*T* (Fig. 127), of the speed gearbox. Lever *3* (Fig. 128) has three

positions which correspond to the three positions of the double cluster gear.

Push-rods *2* actuate lever *1* which is linked through a number of intermediate parts with rod *20* carrying pin *22*. Lever *1* has two positions. In its first position, pin *22* connects segment gear *21* to hollow shaft *24* on which lever *25* is mounted. In the second position, hollow shaft *24* is connected to segment gear *23*. Segment gear *21* meshes directly with a rack cut on sleeve *27*, while segment gear *23* is linked to the same rack through the intermediate pinion *30*. Thus, by shifting lever *25* in one direction, sleeve *27* can be shifted in either of two opposite directions depending upon the position of pin *22*.

Through spring *28* sleeve *27* is linked to rod *29* (Fig. 128) which shifts fork *5* (Fig. 127) in the speed gearbox. Therefore, by shifting lever *25* either the upper or lower section of the twin friction clutch in the speed gearbox will be engaged, thereby changing the spindle speeds. The provision of intermediate gear *30* enables forward rotation of the spindle to be engaged when lever *25* is shifted downward, and reverse rotation when it is shifted upward. The spindle is stopped by setting lever *25* into the middle (neutral) position. The drive motor is switched off in this position of the lever by switch *26*.

In this manner, axial (downward) movement of double-disk member *5* sets the sliding double cluster gear, 29*T* and 51*T* (Fig. 127) of the speed gearbox in the required position, and also prepares the mechanism for the engagement of either the upper or lower section of twin friction clutch *2* (Fig. 127)

The preselection of the spindle speeds consists in turning preselector lever *6*, linked to member *5* and dial *15*, so that the required speed for the next operation is shown on the dial. This turns double-disk member *5* so that the corresponding holes are positioned opposite push-rods *2* and *4*. At the same time, cams *7* and *8*, mounted on the shaft of lever *6*, operate change-over switches *9* and *10* which control the speed and direction of rotation of the two-speed motor. After stopping the machine with lever *25* at the end of an operation and changing the tool, lever *31* is shifted. This lever is linked through lever *11* to member *5* and completes the preparations for starting the drill (member *5* is shifted downward). Then forward or reverse rotation of the spindle is engaged by turning lever *25*. When lever *31* is released, double-disk member *5* is returned to its initial position by spring *19* acting on lever *11*. Consequently, the speed-changing mechanism is ready for the next preselection of spindle speed.

The feed gearbox (Fig. 129) is driven from shaft *VI* of the speed gearbox (Fig. 127) through gears $\frac{30}{66} \times \frac{23}{34}$, shaft *VIII* and further through gears $\frac{17}{39}$ (Fig. 129) to shaft *XI*. Thus, the feed gearbox is linked positively to the spindle through a gear train. Eight rates of feed (0.06 to 1.22 mm per revolu-

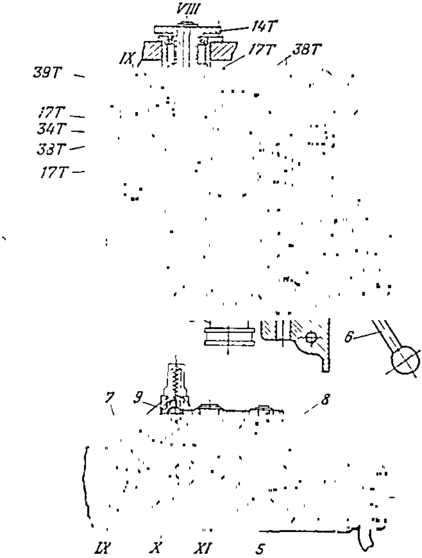


Fig. 129. Feed gearbox of the model 2A53 radial drill

tion) are obtained for each spindle speed by the various engagements of the sliding double cluster gear, 17*T* and 38*T*, on shaft *IX*, and the quadruple cluster gear, 17*T*, 34*T*, 28*T* and 22*T*, on shaft *XI*. These cluster gears are controlled by a single lever *6*. When lever *6* is turned together with drum *1*, bar *1*, on which rack teeth are cut, is shifted vertically by pinion *5*. Fork *2*,

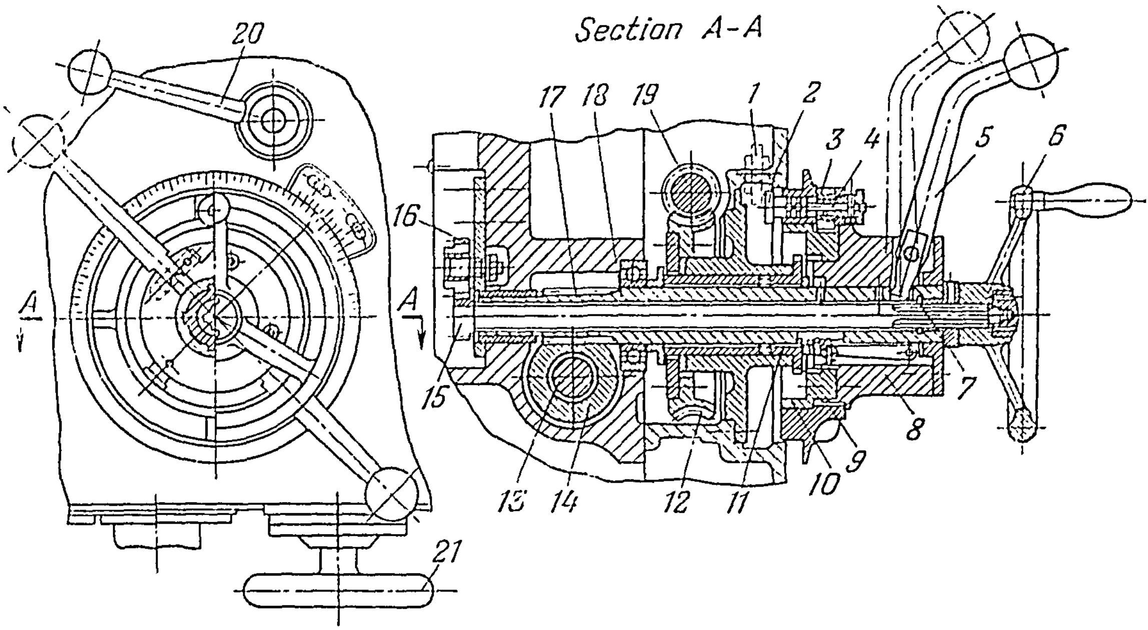


Fig. 130. Feed mechanism of the model 2A53 radial drill

mounted on bar *1*, shifts the quadruple cluster gear to one of four indexed positions.

When lever *6* is turned in the slot of drum *4*, shaft *3* is shifted axially. An annular rack cut on the end of shaft *3* meshes with the pinion on the end of shaft *8*. Rotation is transmitted further through gears to rack *9* on which fork *7* is mounted. This fork shifts the double cluster gear to either of two indexed positions. The feed gearbox is arranged in a separate housing secured to the front face of the drill head housing.

The feed mechanism (Fig. 130) effects power feed of the spindle at the given rate, automatic disengagement of the power feed at a preset drilling depth, fast hand traverse of the spindle, and fine hand feed.

To engage the power feed, head *8*, mounted on the splined end of shaft *18*, is brought into engagement with gear *11* with the aid of levers *5*. For this purpose, disk *10* with internal and external gears is fastened to head *8*.

Gear *11*, mounted freely on shaft *18*, has clutch teeth which engage mating teeth on worm wheel *12*. The worm wheel is driven by worm *19* which is linked to the feed gearbox through toothed clutch *10* (Fig. 129). Pinion *17* on the left end of shaft *18* meshes with the rack cut on quill *14* in which spindle *13* rotates (Fig. 130).

Power feed is automatically disengaged when the required depth is reached by a device consisting of dial *9*, stop *2*, knob *4* with an eccentric neck, and locking member *3*.

By turning knob *4*, mounted on dial *9*, locking member *3* is brought out of engagement with the external gear of disk *10*. This releases the dial which is turned to the required graduation and locked again to disk *10* by locking member *3*. Then knob *4* is moved axially to advance stop *2*. At the end of the preset rotation of the dial, stop *2* depresses roller *1* which is linked with the lever for disengaging toothed clutch *10* (Fig. 129).

To traverse the spindle rapidly by hand levers *5* are turned after disengaging head *8* from gear *11*.

Fine hand feed is obtained by turning handwheel *21* (Fig. 130) mounted on the shaft of worm *19*. Toothed clutch *10* (Fig. 129), in this case, is disengaged by lever *20*.

The drill head is traversed by hand along the arm by turning handwheel *6* which is linked through shaft *7* and gears *15* and *16* with the rack on the arm.

The head is clamped rigidly in the required position on the arm by an eccentric mechanism located at the rear of the head housing.

The outer column is clamped simultaneously with the head.

Drill heads of heavy radial drills provide much wider ranges of speeds and feeds than the smaller machines. The number of speed and feed steps is also increased. Heads of heavy radials are equipped with speed and feed preselector controls. Speeds and feeds are changed by either electromechanical or hydraulic means.

The use of such mechanisms substantially reduces handling time required in changing the speeds and feeds. This circumstance is of especial importance for radial drills since they usually perform operations requiring changes of cutting tools and consequent changes in the speeds and feeds.

Further reduction of time losses connected with speed and feed changing can be achieved by equipping the heads with mechanisms for automatically changing the speeds and feeds when going over from operation to operation.

The most promising current method for introducing automaticity in feed and speed changing involves the use of built-in electromagnetic clutches in the drill head.

In a system of automatic controls, speed and feed changing in a single-spindle head should be connected with the withdrawal of the spindle to the initial position. It should be connected with the indexing of the turret if a turret with several tools is employed.

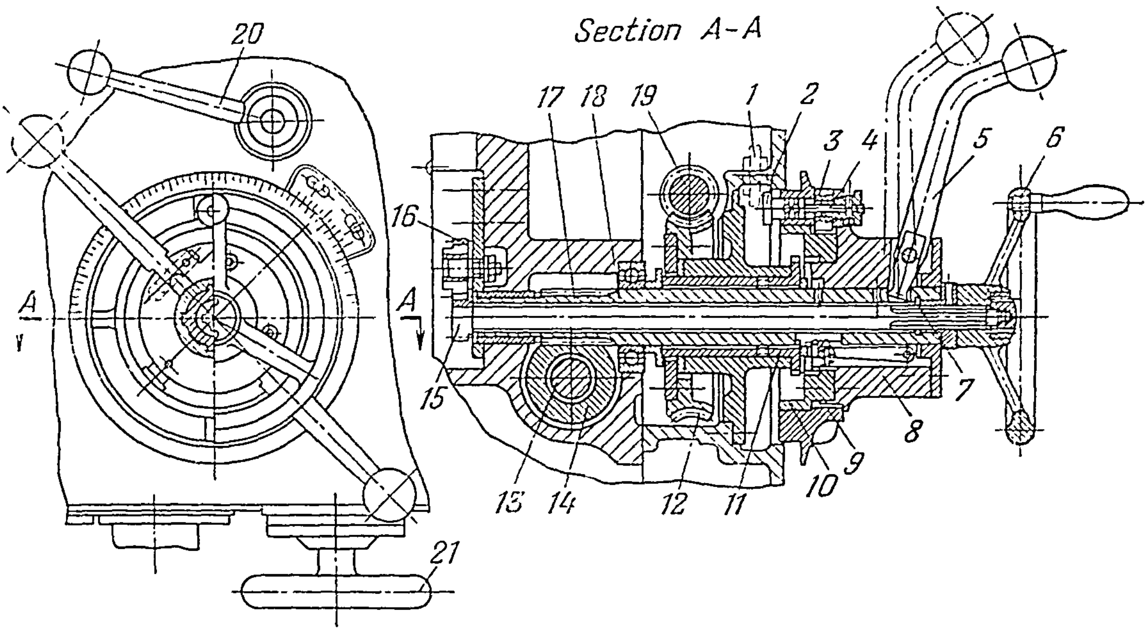


Fig. 130. Feed mechanism of the model 2A53 radial drill

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CHAPTER 6
BORING MACHINES

6-1. Purpose and Field of Application of Boring Machines

Boring machines are designed for machining large, heavy work in piece and lot production of machinery. These machines are highly versatile and can be used for *boring*, *drilling*, *core drilling*, *counterboring*, *spotfacing*, cutting internal and external threads, turning cylindrical surfaces, facing, and peripheral and face milling operations. In many cases, a housing-type workpiece can be completely finished on a boring machine without resetting in other machine tools.

The distinguishing feature of boring machines is the horizontal (or vertical) spindle with axial feed. The cutting tools, such as the boring bar with cutters, drill, core drill, reamer, milling cutter, etc., are secured in the taper hole of the spindle.

Positioning movements to align the spindle axis with the hole to be machined, and feed motions are transmitted to the various units in accordance with the purpose, construction and size of the machine, as well as the character of the operation being performed. General-purpose boring machines are classified into:

(a) horizontal boring machines;
(b) jig borers (see Part II, Chap. 22);
(c) precision boring machines.

6-2. Horizontal Boring Machines

Horizontal boring machines, also known as horizontal boring, drilling and milling machines, can perform all the machining operations mentioned in the preceding section.

The principal dimension of this type of machine is the diameter of the boring spindle which carries the cutting tools.

In a horizontal boring machine the spindle is arranged horizontally. The motions required for performing the machining operations are transmitted to the various units in different ways for machines of different sizes.

Horizontal boring machines of the smaller sizes (with a boring spindle diameter from 50 to 125 mm) consist of the following principal units: bed

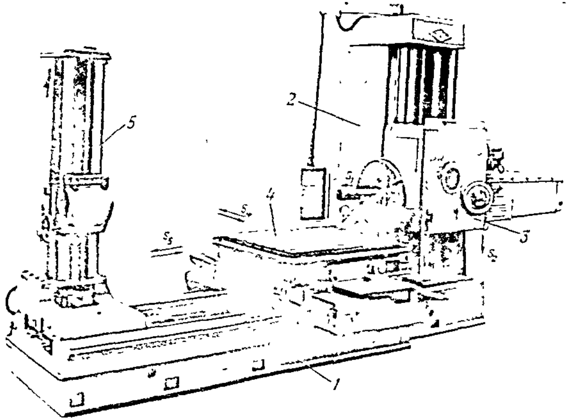


Fig. 131. Table-type horizontal boring machine, model 2A635

1 (Fig. 131), main column 2, headstock 3, table unit 4, and end-support column 5 with the bearing. This is called the table-type machine.

The primary cutting motion v is the spindle rotation. Feed motion is imparted to either the tool or the work, depending upon the type of machining being done. In the first case, the feed motion is either axial feed s_1 of the spindle, vertical feed s_2 of the headstock, or radial feed s_3 of a facing slide on the faceplate. In the second case, the feed motion is table feed in either of two perpendicular directions (s_4 or s_5).

Auxiliary motions include positioning traverse of the headstock in the vertical direction, of the table in two co-ordinate directions, of the end-support column with its bearing, and of the end-support bearing along its column; speed and feed changing; etc.

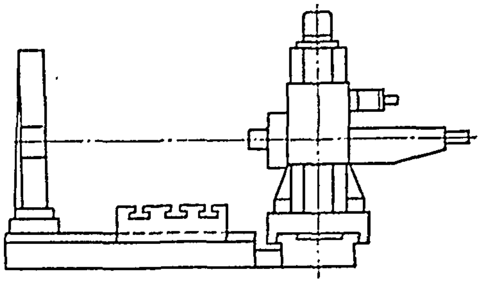


Fig. 132. Medium-size horizontal boring machine

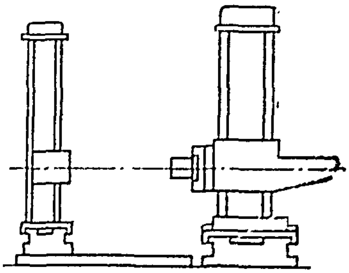


Fig. 133. Floor-type heavy horizontal boring machine

Medium-size machines (with a boring spindle 100 to 200 mm in diameter) consist of the same units as those of smaller sizes (Fig. 132). The table of these machines travels in one direction only, either longitudinally (parallel to the spindle axis) or crosswise. The headstock and end-support columns travel along runways or the bed in either the longitudinal or cross direction. If the table travels crosswise on the bed and the columns travel longitudinally on runways, the boring machine is said to be of the planer type.

Heavy horizontal boring machines (spindle diameter from 125 to 320 mm) have no table, the work being placed on the floor plate (Fig. 133). Such machines are of the floor type.

In the most universal design of floor-type machine the headstock column travels with its saddle in the cross direction along a runway and along the ways of the saddle in the longitudinal direction.

The headstock column may travel at a speed equal to working feed (for milling operations) or at the speed of positioning traverse. The end-support column can travel in the cross direction only.

Either a-c or d-c motors, mounted directly on the headstock, are used for the spindle and feed drives. Small-size machines have a separate motor and gearbox for traversing the table, headstock and end-support column. Heavy machines have multiple-motor drives.

Brief specifications of certain models of Soviet horizontal boring machines are given in Table 19.

6-3. Principal Units of Horizontal Boring Machines

The bed of a horizontal boring machine is a box-shaped grey iron casting stiffened by ribs. Units on which the main column or end-support column travels in the floor- or planer-type machines are called runways.

TABLE 10

Model	Boring spindle diameter, mm	Working surface of table, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx	Remarks
2A614	65	800 × 1,000	20 to 1,600	5.5	6,000	With revolving table
2615	80	800 × 1,000	12 to 1,600	7.5	5,750	Ditto, but without facing slide
2620B	100	1,000 × 1,250	12.5 to 1,600	8.3/10	12,000	Ditto, but with facing slide
2620Пр	100	1,000 × 1,250	12.5 to 2,000	8.3/10	12,500	With numerical controls
2622B	110 (125)	900 × 1,120 (1,000 × 1,250)	12.5 to 1,600	8.3/10	11,800	
2622K	110 (125)	—	12.5 to 1,600	10/7.5	—	Portable
2622Пр	110 (125)	900 × 1,120 (1,250 × 1,600)	12.5 to 1,600	8.3/10	13,500	With numerical controls
2636	125	1,250 × 1,600	6.3 to 1,000	19	25,000	
2637	160	1,250 × 1,600	6.3 to 1,000	19	25,000	
2650	160	—	4 to 800	25	50,000	Planer type table
2651	200	—	4 to 800	25	50,000	Ditto
2Б660	220	—	1 to 510	55	140,000	Floor type with floor plate
2A670	220	—	1 to 510	55	140,000	Ditto
2A680	320	—	0.5 to 250	100	240,000	Ditto

Boring machines of the smaller sizes (table-type) have a one-piece bed with horizontal ways. Medium sizes may have a bed cast in several pieces bolted together, or a bed and one or two runways. In the latter case, the table travels on the bed and the end-support and main columns travel along runways.

The most universal type of heavy boring machine (floor-type) has a floor plate and two runways. The runway along which the main column travels is fastened down separately but on a common foundation plate.

The main, or headstock, column is also a box-shaped casting and has vertical ways along which the headstock travels. It houses the counterweights which balance the headstock to make it easier to move.

Stationary main columns are rigidly secured to the right end of the bed. Those of the travelling type have longitudinal or cross ways on what is called the column base, which is the unit that supports and secures the column.

The headstock travels vertically along the ways of the main column. It contains the speed and feed gearboxes, and the feed mechanisms of the boring spindle and facing slide. In machines of the smaller sizes all these mechanisms are powered from a single motor mounted on the headstock housing. In the heavier models, each mechanism has a separate drive which is frequently a variable-speed d-c motor.

The speed gearbox in the headstock provides for independent rotation of the boring spindle and facing slide faceplate. This allows such operations as boring and facing to be combined.

The construction of the speed gearbox of the model 262Г horizontal boring machine is shown in Fig. 134.

Boring spindle *1* slides back and forth in plain bearings in hollow spindle *2*. Any one of 18 different speeds is transmitted to the boring spindle from the two-speed motor through two triple cluster gears ($24T$-$28T$-$20T$ and $55T$-$30T$-$19T$) and gears $\frac{43}{58}$.

Spindle *3*, carrying faceplate *4*, also has 18 speeds obtained in the same manner but through gears $\frac{22}{58}$ when clutch *6* is engaged.

The speed gearbox has preselector controls. The principle of operation of the mechanism for traversing facing slide *5* of the faceplate is explained in the next section (Sec. 6-4). In heavy boring machines having multiple-motor drives the facing slide is powered from a variable-speed motor mounted inside the faceplate housing (Fig. 135). In this construction d-c motor *1*, through worm *2*, a worm wheel (not shown) and bevel gears $\frac{13}{40}$, transmits rotation to worm *3* which mates with worm rack *4* secured to slide *5*.

The feed gearbox in the headstock of the smaller models is an ordinary multiple-step gearbox with sliding cluster gears.

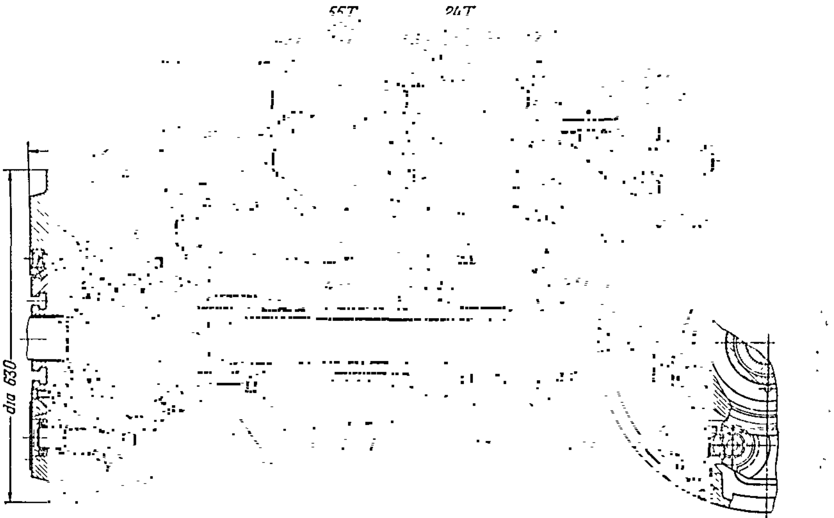


Fig. 134. Speed gearbox of the model 262Г horizontal boring machine

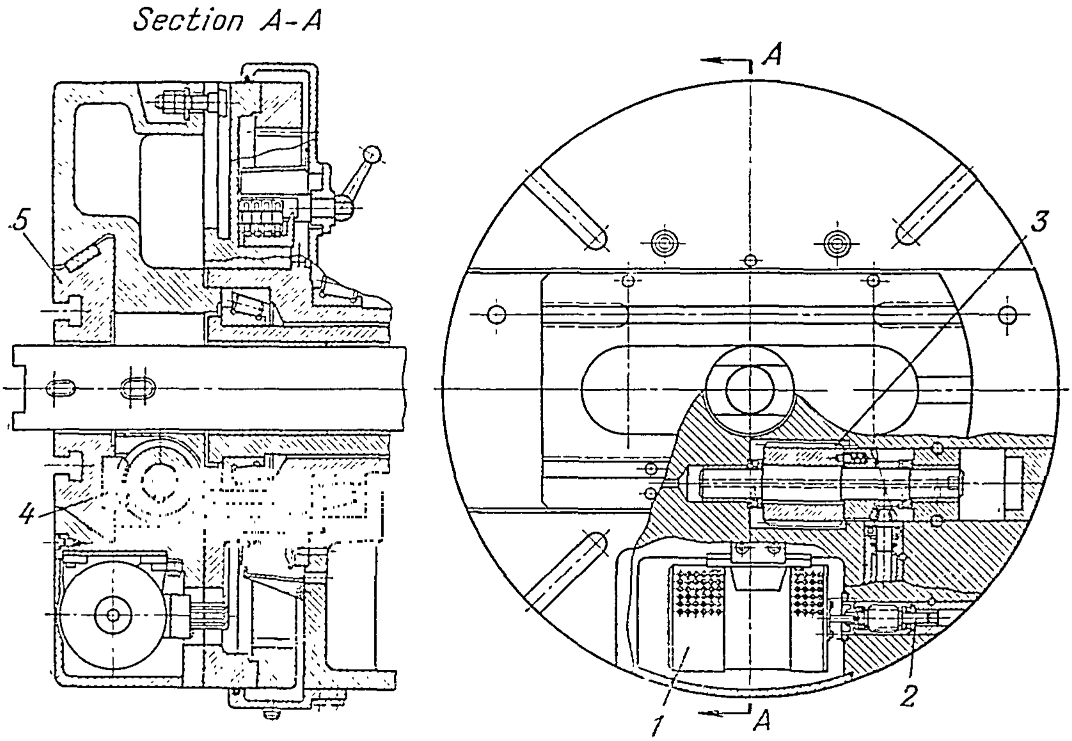


Fig. 135. Facing slide of the model 262Г boring machine

The table unit of the table-type machines consists of the table proper and the saddle. The latter provides a compound movement of the table so that it can travel in the longitudinal as well as the cross direction. The table can travel at the working feed; it also has rapid positioning traverse and hand traverse. Built-in revolving tables have four indexed positions at 90° intervals. The rotating mechanism of such a table provides for power and hand indexing, locking and clamping. Unindexed, intermediate positions of the revolving table are set on a circular scale.

The table of a planer-type machine has no saddle and travels in one direction only directly on the bed ways by means of worm-rack gearing. Variable-speed d-c motors are employed in the drives of the table traverse mechanisms.

The end-support column is a box-shaped casting with vertical ways along which the bearing block travels when it is adjusted into alignment with the boring spindle. The bearing is used to support long boring bars and heavy tools.

6-4. Horizontal Boring Machine, Model 262Г

This machine is intended mainly for the multiple-tool machining of housing-type parts in piece and lot production. The boring spindle is 85 mm in diameter.

The gearing diagram of the machine is shown in Fig. 136.

The speed gearbox transmits 18 forward and reverse speeds to the boring spindle along the following gear train: two-speed motor, V-belt drive $\frac{118}{236}$, triple cluster gear ($20T$, $28T$ and $24T$), triple cluster gear ($30T$, $55T$ and $19T$), helical gears $\frac{43}{58}$ and hollow spindle *2* to boring spindle *1*.

Faceplate *3* also has 18 forward and reverse speeds obtained along the same gear train except for different helical gears $\left(\frac{22}{58}\right)$. The faceplate rotates when clutch *5* is engaged.

Axial motion is transmitted to the boring spindle for all operations, except thread cutting, along the following gear train: boring spindle, gears $\frac{58}{43} \times \frac{35}{56} \times \frac{42}{42}$, triple cluster gear $\frac{22}{46}$ or $\frac{34}{34}$ or $\frac{28}{40}$, double cluster gear $\frac{18}{50}$ or $\frac{34}{34}$, double cluster gear $\frac{18}{50}$ or $\frac{50}{18}$, gears $\frac{50}{42}$, feed engagement clutch *6*, gears $\frac{39}{45}$, bevel gears $\frac{21}{42}$, worm gearing $\frac{4}{29}$, jaw clutch *9*, bevel gear reversing unit with clutch *10*, and gears $\frac{33}{49} \times \frac{49}{33} \times \frac{50}{69}$ to the three-start screw ($t = 8$ mm $\times$ 3).

Axial feed is obtained along the same gear train in thread cutting except that the thread-cutting change-gear quadrant $\frac{a}{b} \times \frac{c}{d}$ takes the place of the last pair of gears $\left(\frac{50}{69}\right)$.

A boring machine of this design has 24 axial feeds. The sliding cluster gears are in the feed gearbox.

Radial feed of the facing slide on the faceplate is driven from the feed gearbox through the following gear train: feed gearbox, worm gearing $\frac{4}{29}$, jaw clutch *9*, gears $\frac{57}{43}$, planetary gearing, gears $\frac{24}{116} \times \frac{116}{22}$, worm gearing $\frac{1}{22}$ and a rack-and-pinion drive ($16T$, module 3 mm).

The facing slide will be fed only if the faceplate and gear $116T$ rotate at different speeds, since it is necessary for pinion $22T$, mounted in the faceplate, to roll around gear $116T$. The two elements will run at different speeds if the driving shaft of the planetary gearing is driven in either direction through the above-described radial feed gear train

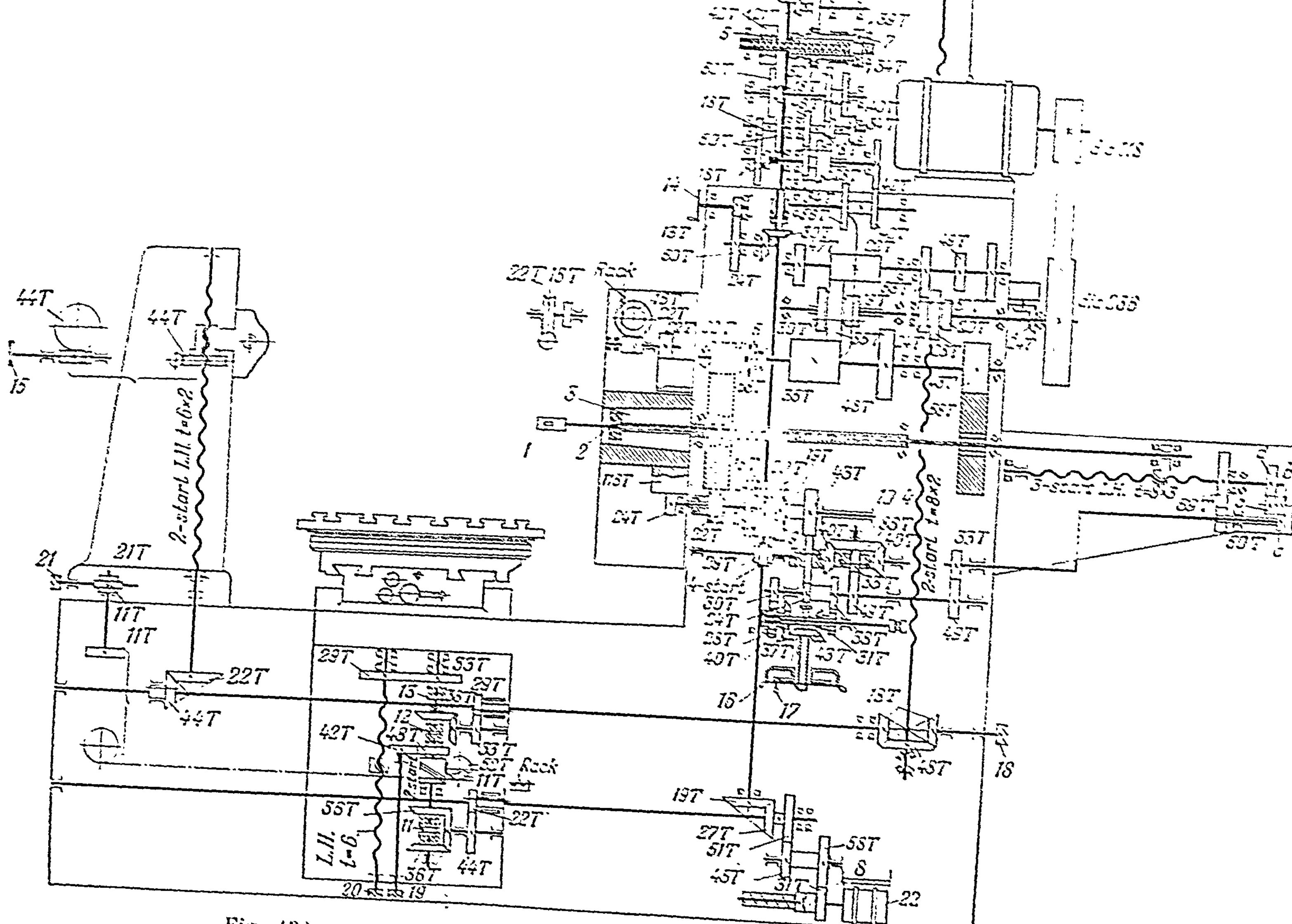


Fig. 136. Gearing diagram of the model 262Г horizontal boring machine

Vertical feed of the headstock is effected through the following gear train: boring spindle, gears $\frac{58}{43} \times \frac{35}{56}$, feed gearbox, bevel gears $\frac{19}{27}$, gears $\frac{22}{44}$, bevel gear reversing unit with clutch *11*, bevel gears $\frac{36}{36}$, gears $\frac{33}{29}$, and bevel gears $\frac{18}{48}$ to the two-start screw *4* ($t = 8$ mm $\times$ 2).

Longitudinal travel of the table is obtained through the gear train: boring spindle, gears $\frac{58}{43} \times \frac{35}{56}$, feed gearbox, gears $\frac{19}{27} \times \frac{22}{44}$, bevel gear reversing unit, worm gearing $\frac{2}{52}$ with clutch *12*, and a rack-and-pinion drive (*11T*, module 5 mm).

Cross travel of the table is linked to boring spindle rotation through the same gear train except that following the bevel gear reversing unit, rotation is transmitted by gears $\frac{33}{29}$, included in the gear train when clutch *13* is engaged, to the two-start screw ($t = 6$ mm $\times$ 2).

Rapid positioning traverse is imparted to the headstock and table by a separate motor *22*; at the same time, the feed engaging clutch *6* is disengaged.

The various units are traversed by hand by turning the handwheels from *14* to *21*, inclusive.

Clutches *7* and *8* protect the feed and rapid traverse mechanism against overloads.

6-5. Attachments and Accessories of Horizontal Boring Machines

The work is set up and clamped on the table of a horizontal boring machine with the aid of clamping accessories such as supports, T-bolts and

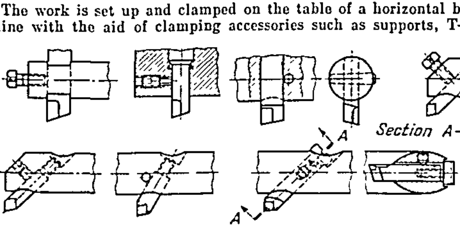


Fig. 137. Methods of clamping cutters in boring bars

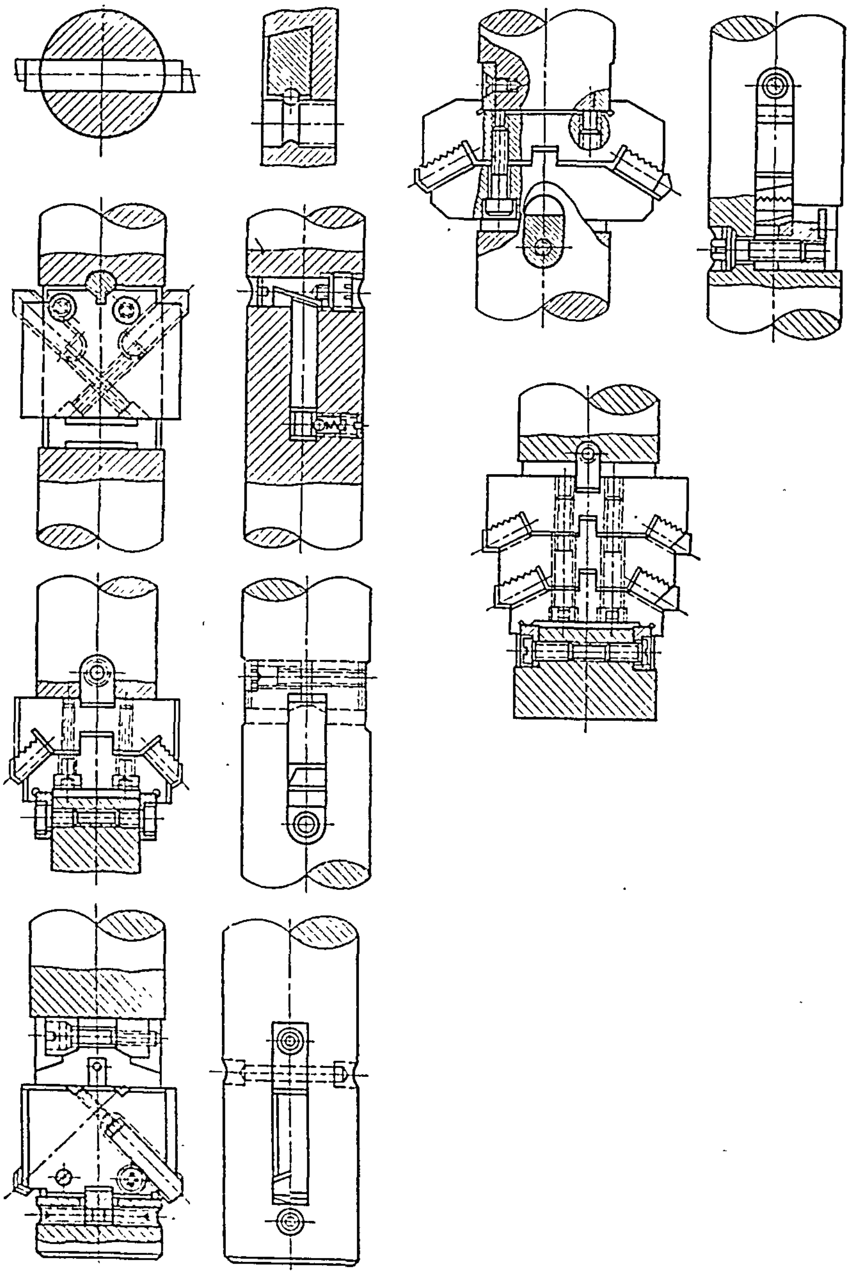


Fig. 138. Methods of clamping block cutters and reamers in boring bars

strap clamps, assembled clamps, etc. The table is provided with T-slots that are used in securing these accessories.

Rapid-action fixtures with mechanical, hydraulic or pneumatic clamping facilities are commonly used in lot production. Such fixtures frequently locate the work in addition to clamping.

The nose of the boring spindle has a tapered hole with a metric or Morse taper in which such tools as drills, reamers and milling cutters are held either directly or through sleeves and sockets.

Boring cutters are clamped in either stub or long boring bars. Stub bars are inserted into the tapered hole of the boring spindle. Long boring bars, with the free end supported in the bearing of the end-support column, are

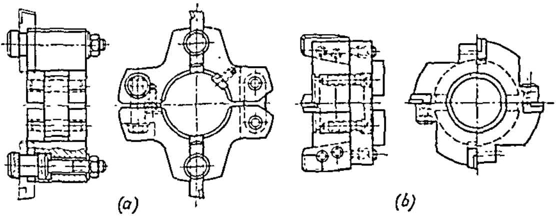


Fig. 139 Boring heads:
(a) split; (b) solid

used to bore several coaxial holes in the end and intermediate walls of housing-type work.

Methods used for clamping cutters in boring bars are illustrated in Fig. 137.

Block cutters and reamers are clamped in boring bars with the aid of lock keys, flat keys or tapered thrust plates (Fig. 138).

Split and solid boring heads (Fig. 139*a* and *b*), used in roughing holes of a diameter over 150 mm, are held on boring bars with keys and clamping bolts.

6-6. Trends in Horizontal Boring Machine Design

The rapidly developing engineering industries are continuously raising their requirements as to the accuracy and surface finish of machined parts. Therefore, new models of general-purpose horizontal boring machines are designed to combine to some extent the advantageous features of horizontal boring machines, jig borers and precision boring machines.

Special optical devices enable the boring spindle to be set to co-ordinate dimensions with a high degree of precision. In some cases this allows horizontal boring machines to be used in place of the more expensive jig borers.

The development of machines incorporating controls which set the spindle to a series of given co-ordinate dimensions in the required sequence enables the machines to be operated with an automatic cycle even under small-lot production conditions.

The use of infinitely variable hydraulic feeds in the newer models, devices for hydraulically relieving the pressure in the ways, and the provision of higher boring spindle speeds enable horizontal boring machines to be used for precision ("diamond") boring as well.

6-7. Precision Boring Machines

Precision boring machines are designed for the precision, or diamond, boring of holes that are cylindrical to within 3 or 5 microns (0.003 or 0.005 mm). A surface finish from the 7th to 9th classes, inclusive, according to USSR Std GOST 2789-59, can be produced by this processing method. It finds wide application in boring the cylinders of aircraft and automobile engines, certain components of pumps and machine tools, and is sometimes employed in repair operations.

Depending upon the arrangement of the axis of rotation of the spindle, precision boring machines are classified as vertical (Fig. 140) and horizontal (Fig. 141). As to the number of spindles, they may be single- or multiple-spindle models. Horizontal precision boring machines may be single-end (holes bored from one end) or double-end machines.

Table 20 lists brief specifications of Soviet precision boring machines.

The primary cutting motion v in a precision borer is the rotation of the spindle which carries the single-point tool (Figs. 140 and 141).

In the single-spindle vertical machines the feed motion s is imparted to the spindle; in the horizontal single- and double-end machines it is imparted to the table on which the fixture for holding the work is mounted.

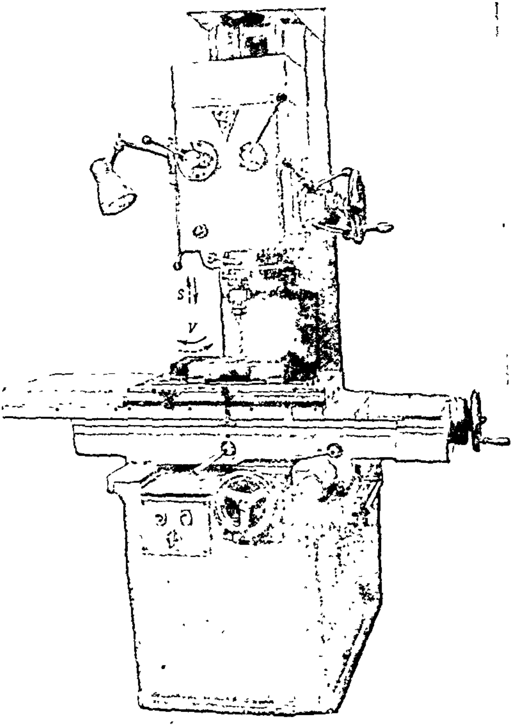


Fig. 140. Vertical precision boring machine, model 2918

TABLE 20

Model	Working surface of table, mm	Table travel, mm	Maximum diameter bored, mm	Range of spindle speeds, rpm	Available power, kW	Net weight, kg approx.	Remarks
2705	320×500	280	—	Up to 5,000	1.5 to 3	2,000	Horizontal, single-end
2706	320×500	450	—	Up to 5,000	1.5 to 3	2,100	Ditto
2712A	500×710	630	—	50 to 1,250	2×2	4,500	Ditto
2714	800×1,000	—	—	Up to 1,000	1 to 5.5	9,000	Horizontal, double-end
2709	320×500	—	—	350 to 3,500	1.5	6,500	Semiautomatic with programmed cycle
2A865	—	—	125	98 to 392	0.5	65	Portable
278	—	—	165	80 to 450	1.5	2,250	Vertical, single-spindle
2A78	—	—	200	26 to 1,200	1.5/2.2	2,500	Ditto
278M	—	—	200	26 to 1,200	1.5/2.2 (each spindle)	3,000	Multiple-spindle

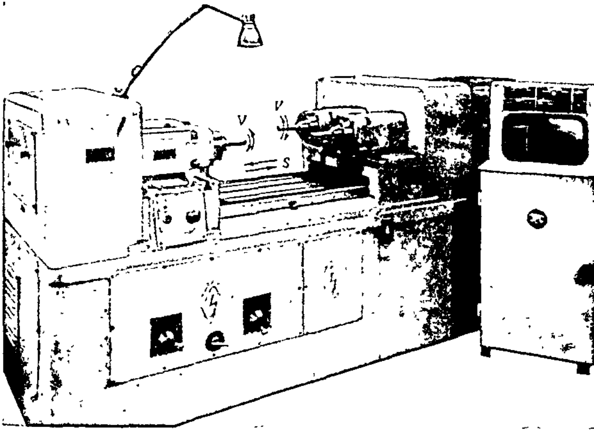


Fig. 141. Horizontal precision boring machine, model 2706

The table has a complex cycle of working feeds and rapid traverse movements, advancing the work first to one and then to the other boring head (in the double-end models) which are mounted on fixed bridges.

The feed motion is imparted to the boring spindles in special-purpose precision borers, while the work is held stationary.

The single-spindle vertical precision boring machines have a divided main drive, i.e., rotation is transmitted from the speed gearbox (reducing gear) in the column by means of a belt drive. In a drive of this construction, the forced vibrations that are excited in the speed gearbox are not transmitted to the boring spindle to any great extent This has a favourable effect on the surface quality of the bored hole in the work. Horizontal machines designed for higher accuracy have no speed gearbox and the drive motor

is mounted separately from the machine proper so that rotation is transmitted to the boring spindles only through a belt drive.

Spindle speeds are varied by means of stepped or change pulleys.

The spindles of precision boring machines run in precision plain or antifriction bearings. Antifriction bearings are of the preloaded type. Frequently, the spindle unit is designed with means for automatically eliminating excess clearances due to wear or thermal deformation.

Feeds are usually obtained by a hydraulic drive providing for stepless feed variation. The advantage of such a drive is the possibility of obtaining the very small feeds (less than 10 mm per min) that are employed in precision boring. Moreover, the application of a hydraulic drive facilitates the automation of the feed cycle.

To increase the production capacity of precision boring machines operating on a semiautomatic cycle, they are equipped with an in-process gauging system with a feedback function that automatically adjusts the cutting tool to compensate for its wear.

CHAPTER 7

UNIT-BUILT MACHINE TOOLS

7-1. Purpose of Unit-Built Machine Tools and Their Layout

Unit-built machine tools are special machine tools consisting of standard units.

Such machines find application in the multiple-tool machining of various workpieces (mostly of the housing type) in large-lot and mass production. They are extensively employed in plants manufacturing automobiles and agricultural machinery.

Unit-built machine tools are designed for such operations as drilling, boring, threading and, less frequently, for milling surfaces. Unit-built machines that perform elementary assembling operations have been developed in recent years.

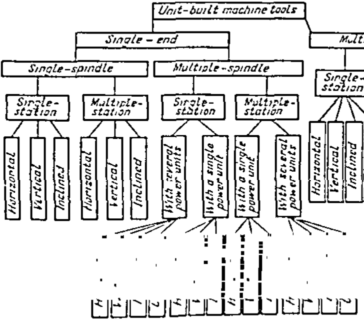


Fig. 142. Classification of unit-built machines according to their construction arrangement

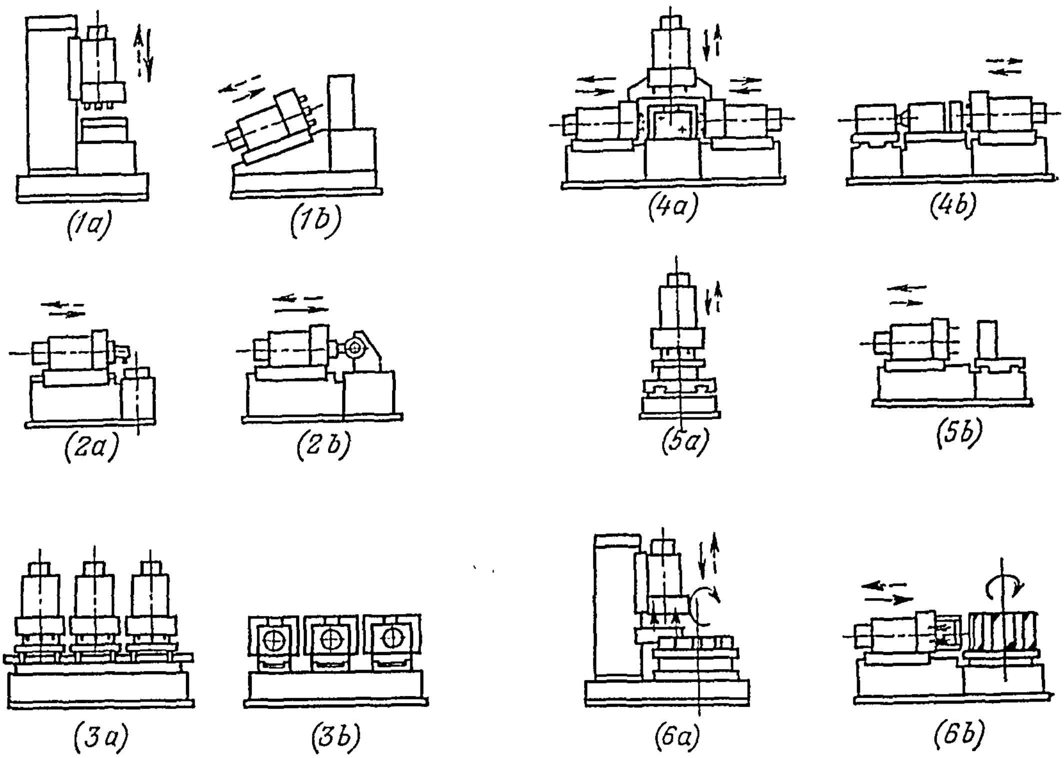


Fig. 143. Examples of unit-built machine tool design:

1—single-end single-station machine tool: *a*—vertical; *b*—inclined; 2—single-end single-station machine tool for machining surfaces of revolution and with the work held: *a*—in the power unit; *b*—in a fixture of a sub-base; 3—single-end single-station gang-type machine tool: *a*—vertical; *b*—horizontal; 4—multiple-way single-station machine tool: *a*—four-way; *b*—two-way; 5—single-end multiple-station machine tool with a travelling table: *a*—vertical; *b*—horizontal; 6—single-end multiple-station machine tool with a revolving table: *a*—vertical; *b*—horizontal

Advantages ensuing from the proper application of unit-built machine tools include: (a) a substantial reduction in the time required to design and manufacture a special machine tool; (b) high production capacity due to multiple-tool machining and a minimum amount of handling motions; (c) comparatively low manufacturing cost; (d) reduction in the costs of machining workpieces on the machine tool due to the high productivity and simple servicing; (e) a more readily automated machining cycle; and (f) the possibility of using some of the standard units again if changes are made in the product being manufactured.

In cases when an established assortment of parts is being manufactured, it is possible to design unit-built machine tools that can handle several similar parts of different sizes by changing over from part to part.

Unit-built machine tools can operate as individual machines or they can be components of automatic transfer machines or automated production lines.

In most cases, the operation of a unit-built machine tool consists in the machining of a stationary workpiece by a number of cutting tools. Observance of this principle enables machines to be designed in which the units carrying the tools travel only in one direction and allow the work to be machined simultaneously from several sides.

The arrangement of the units depends upon the size and shape of the work, as well as upon the possibility of combining several machining operations.

Figure 142 gives the classification of unit-built machine tools in accordance with their layouts. Examples of such layouts are illustrated in Fig. 143.

7-2. Principal Units of Unit-Built Machine Tools

In the majority of cases, a unit-built machine tool (Fig. 144) consists of: beds *1*, column *1*, power units *2*, multiple-spindle heads *3*, fixture *5* for locating and holding the workpiece and fixture base *6*.

In some cases, the beds or columns are mounted on sub-bases which are also standard units. If several workpieces are to be machined consecutively, stationary fixture *5* is replaced by a movable two-position fixture or by a revolving table on which are mounted fixtures for locating and clamping the workpiece.

Unit-built machine tools with a hydraulic drive of the operative units use standard hydraulic control panels to control the operating cycle.

Standard beds, sub-bases and columns are castings or weldments of box shape with ways for the travel of the power unit. Special nonstandard beds are of welded steel plate construction, as a rule, and have separate hardened steel ways secured by screws In many cases, the ways are designed in the form of a saddle that is mounted on the welded bed after it is completely machined.

Multiple-spindle heads accommodate the tool spindles and transmit rotation from the output shaft of the power unit to the spindles.

Standard multiple-spindle heads (Fig 145) consist of housing *2*, intermediate plate *3*, front *1* and rear *1* covers Standardized spindles, shafts and gears are mounted in the bores of the housing and intermediate plate. Central gear *5* meshes with a gear mounted on the output shaft of the power unit. The components of the head are assembled through the opening in housing *2*. The rear cover has holes for securing the head to the housing of the power unit.

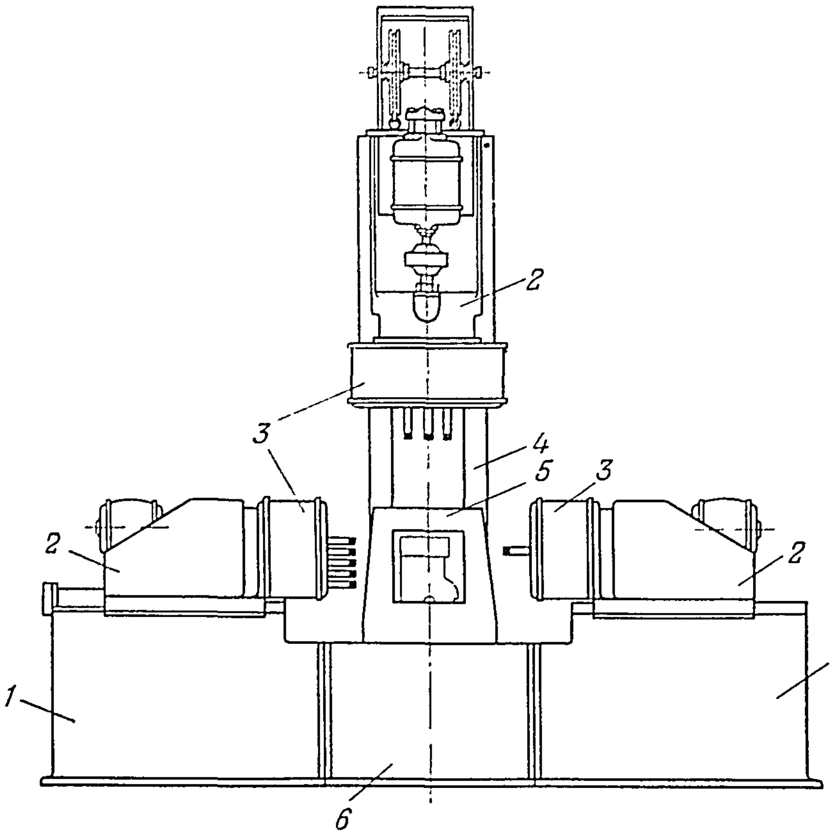


Fig. 144. Three-way multiple-spindle drilling machine

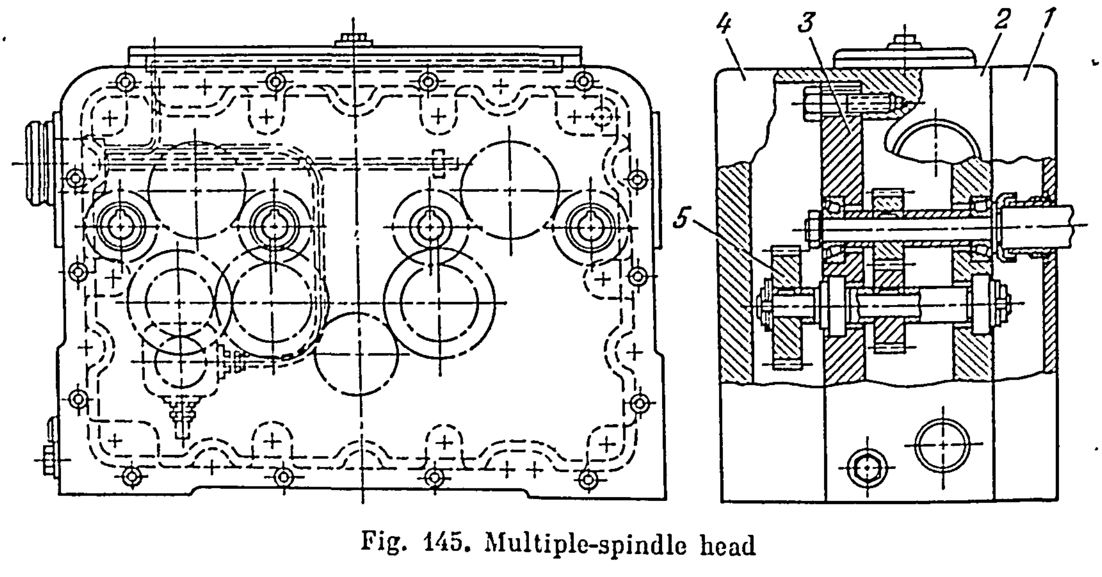


Fig. 145. Multiple-spindle head

A size range of spindle heads has been standardized. The component castings of the heads are manufactured to the standardized dimensions and stored as stock. The holes for the bearings are bored in each particular case to suit the workpiece that is to be machined by the machine tool.

Fixtures or jigs for locating and holding the workpiece are designed in accordance with the size and shape of a definite workpiece, and the type of machining operation to be performed. Therefore, they cannot be standardized. The workpiece is located in the fixture by rest buttons, pads, locating pins, V-blocks, etc.

Adjustable locators, such as jackscrews and spring jack pins, are brought into contact with and additionally support an insufficiently rigid workpiece at certain definite points.

Self-locking mechanisms (wedge, screw or eccentric cam clamps) operated by hand, power or with a combination air-and-hydraulic drive are used to clamp the work in the fixture.

The walls of the fixture (or rather jig, in this case) are frequently used for mounting fixed or rotary bushings that increase the accuracy with which the cutting tools are aligned with the work.

Fixture bases are not standardized and are designed for each particular case in the form of a box-shaped casting or steel weldment.

7-3. Power Units

Power units may be self-contained or separate-feed types.

Self-contained standard power and feed units are ones that impart both rotary and feed motions to the cutting tool, and can be mounted on the machine tool in any required working position.

The separate-feed type of power unit imparts only rotary motion to the cutting tool, the drive of the feed motion being arranged separately in the bed (or column) of the machine tool.

Special thread-cutting power units with reversible spindles are used for threading operations.

A number of types of self-contained power units have been standardized in the USSR.

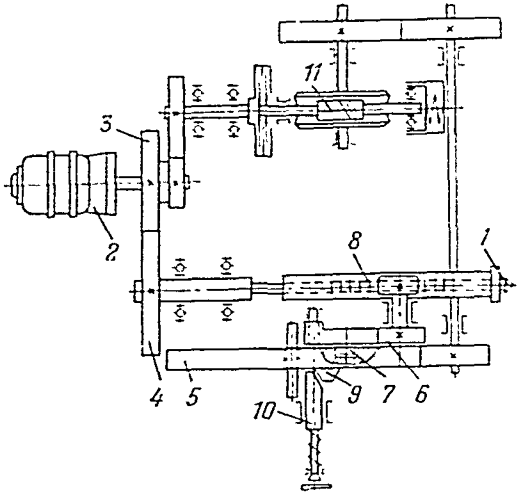
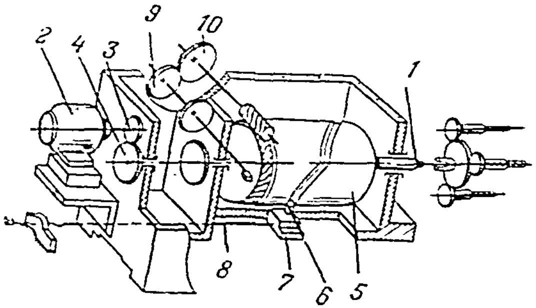
The feed motion in a power unit may be obtained by:

(a) travel of the power unit housing which carries the spindle head;

(b) travel of a quill containing the rotating spindle with the cutting tool, the housing being stationary.

Power units can operate with a wide range of different feed and traverse cycles. The simplest cycle is one in which the unit travels back and forth at the same speed.

TABLE 21

Type of feed drive	Type of unit	Diagram	Brief description
Electromechanical feed drive	Plate-cam-actuated		Rotation of spindle *1* (primary cutting motion v) is obtained from motor *2* through gears *3* and *4*. Upon rotation of feed plate cam *5*, segment gear *6* is turned since it is linked to the cam through roll *7*. As the segment gear is turned, quill *8*, carrying tool spindle *1*, travels at the rate of working feed (s) and rapid traverse. When cam *5* makes one revolution, dog *9* runs up against retractable stop *10*. At this, worm *11*, continuing to rotate, moves axially and disengages the friction clutch. To repeat the cycle, stop *1*, is retracted by a solenoid from dog *9*.
	Drum-cam-actuated		Power is transmitted from motor *2* through gears *3* and *4* to provide rotation of output shaft *1* (primary cutting motion v). Feed drum *5*, arranged in the housing of the unit, engages roll *6* of slide block *7*, secured to the bed with adjusting screw *8*. Upon rotation of the drum, the housing of the unit and the spindle head travel at the rate of the working feed (s) and rapid traverse. The rate of working feed and speed of rapid traverse are set up with change gears *9* and *10*. The power unit is set to the required initial position by screw *8*.

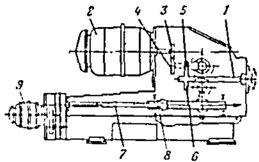
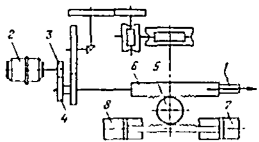
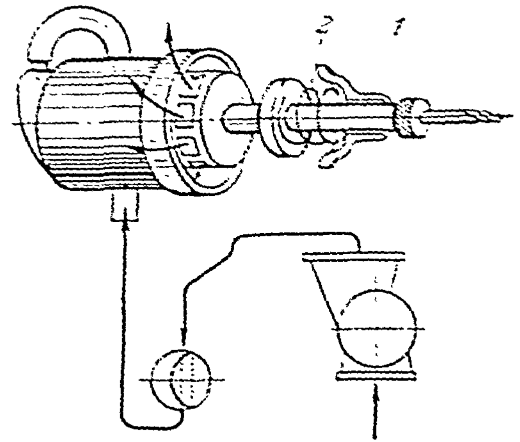
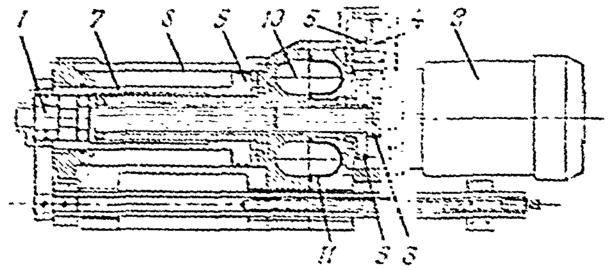
Electromechanical feed drive	Screw-actuated		Rotation (v) of output shaft *1* of the power unit is obtained from motor *2* through gears *3*, *4*, *5* and *6*. Travelling motion is effected by screw *7* and nut *8*. Upon working feed (s), nut *8* is driven from motor *2* through a system of spur and worm gearing. The feed motion is imparted to the whole unit carrying the spindle head. Motor *9*, mounted on the bed, powers the rapid traverse movements. Through the two-direction overrunning clutch (not shown), motor *9* rotates screw *7* at a high speed in either direction.
Pneumatic feed drive	Combined pneumatic and mechanical operation		The rotation of spindle *1* (primary cutting motion v) is powered by motor *2* through gears *3* and *4*. Rack-and-pinion mechanism *5* and *6* effects traverse of the unit. Working feed (s) is effected by motor *2* through a system of spur and worm gearing to pinion *5*. To obtain rapid traverse movements, a rack, actuated by air cylinders *7* and *8*, drives pinion *5*. When air cylinder *7* or *8* is in operation, the working feed gear train is disengaged by an overrunning clutch or a friction clutch (neither is shown), respectively.

TABLE 21 (continued)

Type of feed drive	Type of unit	Diagram	Brief description
Pneumatic feed drive	Air-operated		Rotation of spindle *1* (primary cutting motion v) is effected by a pneumatic motor arranged inside the housing of the unit. The feed air cylinder is in the same housing. Rapid approach of the spindle continues until the tool reaches the work; the subsequent working feed (s) depends upon the hardness of the material being machined. The spindle is returned to the initial position by the action of spring *2*.
feed drive	oil through an member		Rotation of spindle *1* (primary cutting motion v) is powered from motor *2* through gears *3*, *4*, *5* and *6*. Rapid traverse and working feed (s) motions of quill *7*, carrying spindle *1*, are effected by cylinder *8* with piston *9*. The left end of the cylinder is filled with oil. At the beginning of the cycle compressed air is admitted into the right end of the cylinder. This causes rapid traverse of piston *9* and quill *7*. Oil

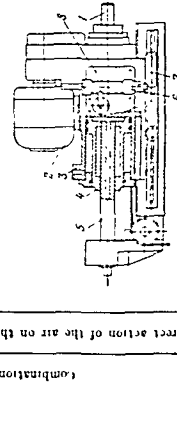
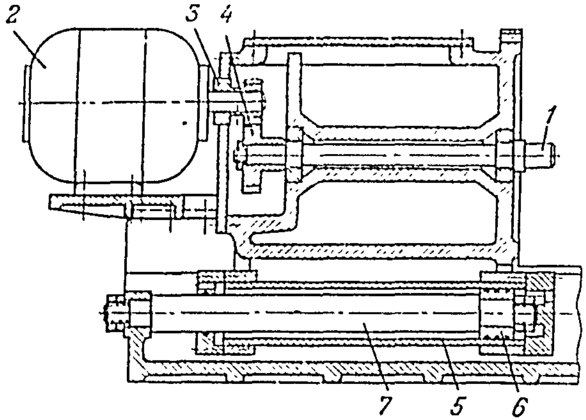
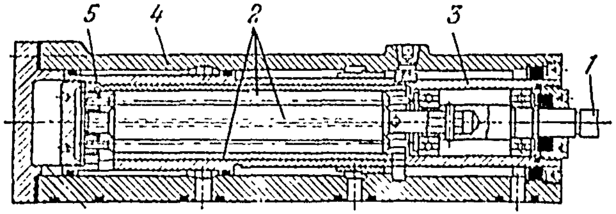
Combination air-and-hydraulic	With action of thevalve on the intermediate		from the left end of the cylinder is forced into cavity *10* where it acts on diaphragm *11*. At the required moment, the valve gear directs the oil through a pressure-reducing valve and a throttle valve to cavity *10*. This provides the working feed (*s*). At the end of the working feed, air is admitted into the left part of cavity *10*. Acting on the other side of the diaphragm, the air forces the oil into the left end of cylinder *8*. At this, the quill is rapidly returned to the initial position. The diaphragm prevents mixing of the oil and air.
	With direct action of the air on the oil		Rotation of output shaft *1* (primary cutting motion *v*) is driven by motor *2* through gearing. Cylinder *3* and piston *4* provide traverse of the unit. Piston rod *5* is secured to the stationary bed. The left end of the cylinder is filled with oil. Rapid approach is effected by air admitted into the right end of the cylinder through the hollow piston rod. This forces the oil out of the cylinder and into reserve tank *8*. At the end of rapid approach, valve *6* is tripped by dog *7* so that the oil passes through a pressure-reducing and a flow-control valve on its way to the reserve tank. This provides the working feed (*s*). At the end of the working feed air is directed to the reserve tank from which it forces oil into the left end of cylinder *3*. This rapidly returns the unit to the initial position.

TABLE 21 (continued)

Type of feed drive	Type of unit	Diagram	Brief description
Hydraulic feed drive	With hydraulic feed drive		Rotation of output shaft *1* (primary cutting motion *v*) is powered by motor *2* through gears *3* and *4*. Reciprocation of the unit carrying the spindle head is effected by hydraulic cylinder *5* with piston *6* and stationary piston rod *7*. The working feed (*s*) can be regulated by throttling (flow-control) or by using a variable-displacement pump (volume-control). The proper sequence of rapid traverse and working feed movements is maintained by a standard control panel.
	With a screw-type hydraulic motor and a hydraulic feed drive *		Rotation of spindle *1* (primary cutting motion *v*) is effected by a screw-type hydraulic motor *2*. Quill *3*, carrying the spindle with the hydraulic motor, is reciprocated by cylinder *4* with piston *5* whose rod is quill *3*. The advantage of this construction is the compact arrangement, in conjunction with ample power and a high spindle speed.

* The power unit with a screw-type hydraulic motor was developed by the Institute for Process Engineering Research in the USSR Tractor and Agricultural Machinery Industries.

An example of a complex cycle is one used in deep-hole drilling in which the drill is repeatedly withdrawn by a rapid traverse movement to clear the chips and advanced at the same speed into the hole, operating at working feed in the actual drilling process.

Accurate spotfacing operations can be performed by dwell (operation without feed) of the power unit as it runs against a positive stop at the end of its stroke.

In most cases, the tool spindles are driven from a motor mounted on the power unit housing.

A great variety of travel mechanisms are employed in the different constructions of power units.

Table 21 contains the classification, schematic drawings and brief descriptions of the more common standard power units.

CHAPTER 8

MILLING MACHINES

8-1. Purpose and Types of Milling Machines

Working, or shape-generating, motions, typical of milling machines, comprise continuous cutting tool rotation, determining the cutting speed, and a rectilinear, rotary or helical feed motion. The feed motion is usually transmitted to the work, and only rarely to the cutting tool.

Milling machines are employed for machining flat surfaces, contoured surfaces (die impressions, punches, cams, etc.), surfaces of revolution, external and internal threads, helical surfaces of various cross section, etc.

Milling machines can be classified according to their application into the following groups: general-purpose, single-purpose and special milling machines. The last-mentioned are designed for performing one or several definite milling operations on definite workpieces. They are used in mass and large-lot production. Table 22 lists data on the dimensional accuracy and surface finish attained in milling.

TABLE 22

Milling	Grade of accuracy		Surface finish class
	Limits	Mean economically feasible	
Roughing	3a-5	4	4-5
Finishing	2a-4	3	5-7
Precision	2a-4	3	7-8

8-2. General-Purpose Milling Machines

General-purpose milling machines are extremely versatile and are employed in piece and small-lot production for machining a wide variety of parts. This group includes: knee-type, bed-type, planer-type and rotary-table milling machines.

The main dimension of general-purpose milling machines is the size of the working surface of the table.

The principal dimensional data on the most extensively used Soviet milling machines are listed in Table 23.

Knee-Type Milling Machines

The special feature of the knee-type machine is the availability of three different directions of table motion. This subgroup is further divided into plain horizontal, universal horizontal, vertical and ram-head knee-type milling machines.

Plain horizontal knee-type milling machines have a horizontal spindle. The tables of these machines can travel in three perpendicular directions.

The plain horizontal milling machine, model 6M83Г, illustrated in Fig. 146, comprises column *1*; knee *2*, travelling along the vertical ways of the column face; saddle *3*, which can travel crosswise along the horizontal ways on the knee; table *4*, having longitudinal travel along the horizontal ways of the saddle; overarm *5* and arbor support *7*, for supporting the outer end of the cutter arbor; and braces *6*, which link the overarm with the knee to increase the rigidity of the machine.

The gearing diagram of a milling machine (models 6M80Г, 6M80) is shown in Fig. 147. The spindle is powered from a flange-mounted motor (2.8 kW and 1,420 rpm) through a six-stage gearbox (three engagements between shafts *I* and *II*, and two between shafts *II* and *III*), V-belts with a 1 : 1 transmission ratio, and the countergearing $\frac{31}{83} \times \frac{24}{71}$. Thus, any one of the six lower speeds can be transmitted to the spindle.

To obtain the six higher speeds, jaw clutch C_1 is engaged. This simultaneously shifts the cluster gear 83*T*-24*T* of the countergearing out of engagement, and the V-belts become the last link of the spindle drive train.

Consequently, the spindle has a total of twelve speeds which range from 36 to 1,600 rpm, or from 50 to 2,240 rpm in the high-speed model.

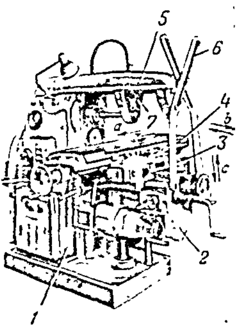


Fig. 146. Plain horizontal knee-type milling machine, model 6M83Г

a, *b* and *c* longitudinal, cross and vertical table travel respectively

TABLE 23

General-Purpose Milling Machines

Type	Model	Working surface of table, mm	Range of spindle speeds, rpm	Power of drive motor, kW	Net weight, kg approx.
		Knee-Type Milling Machines			
Plain horizontal Vertical	6Н803Г 6Н103	125 × 500	315 to 4,000	0.75/1	500
Plain horizontal Vertical	6Н804Г 6Н104	160 × 630	71 to 3,150	2.2	700
Plain horizontal Universal horizontal Ram-head Vertical	6Н80Г 6Н80 6Н80Ш 6Н10	200 × 800	36 to 1,600 (or 50 to 2,240 in high-speed model)	3	1,340
Plain horizontal Universal horizontal Ram-head Vertical	6М81Г 6М81 6М81Ш 6М11	250 × 1,000	40 to 2,000	4	2,000
Plain horizontal Universal horizontal Ram-head Vertical	6М82Г 6М82 6М82Ш 6М12ПБ	320 × 1,250	31.5 to 1,600 (or 125 to 2,000 in high-speed model)	7.5 (10)	2,500
Plain horizontal Universal horizontal Ram-head Vertical	6М83Г 6М83 6М83Ш 6М13ПБ	400 × 1,600	31.5 to 1,600 (or 125 to 2,000 in high-speed model)	10 (19)	3,800
Plain horizontal Ram-head Vertical	6Н84Г 6Н84Ш 6Н14	500 × 2,000	25 to 1,250	13	6,700

TABLE 23 (continued)

Type	Model	Working surface of table, mm	Range of spindle speeds, rpm	Power of drive motor, kW	Net weight, kg approx
Vertical-Spindle Compound-Table Milling Machines					
Swivel-head Tracer-controlled Rotary-table	654 6M54 654K	630 × 1,600 dia 630	25 to 1,250	13	10,000
Fixed-head Swivel-head Rotary-table Tracer-controlled	6A56 6A56H 6A56HK 6M56	800 × 2,000 dia 800	25 to 1,250	17	16,300
Fixed-head Rotary-table Swivel-head	6A59 6A59K 6A59H	1,000 × 2,500 dia 1,000	25 to 1,250	22 30	21,000
Fixed-Bed and Planer-Type Milling Machines					
Simplex or openside (duplex or double-housing) with one horizontal spindle (one on each column)	6303 (6603)	320 × 1,000	40 to 2,000	3 (3 × 2)	3,400 (4,900)
	6304 (6604)	400 × 1,250	40 to 2,000	4 (4 × 2)	4,000 (5,300)
	6305 (6605)	500 × 1,600	25 to 1,800 50 to 1,600	7.5 (7.5 × 2)	6,300 (7,500)
With crossrail and one rail head	6306 (6606)	650 × 2,200	47.5 to 600	10 × 2 (10 × 3)	18,000 (22,500)
	6308 (6608)	800 × 3,000	25 to 800 or 40 to 1,250	13 × 2 (13 × 3)	24,500 (27,000)

TABLE 23 (continued)

Type	Model	Working surface of table, mm	Range of spindle speeds, rpm	Power of drive motor, kW	Net weight, kg approx.
With one (two) rail head(s) and one (two) side head(s)	6310 (6610)	1,000 × 4,000	25 to 800 or 40 to 1,250	17 × 2 (17 × 3)	31,500 (35,000)
	6У312 (6У612)	1,250 × 4,000	25 to 1,250	22 × 2 (22 × 4)	38,000 (49,000)
	6У316 (6У616)	1,600 × 5,000	25 to 1,250	22 × 2 (22 × 4)	49,000 (63,500)
	6320 (6620)	2,000 × 6,300	20 to 1,000	30 × 2 (30 × 4)	63,500 (78,500)
	6325 (6625)	2,500 × 8,000	20 to 1,000	30 × 2 (30 × 4)	98,000 (118,000)
Double-housing with two rail and two side heads	6640	4,000 × 12,000	12.5 to 500	40 × 4	400,000
Combination planing and milling machine	6У632	3,200 × 10,000	12.5 to 500	40 × 4	314,000
Rotary-Table Milling Machines					
Horizontal-spindle	ГФ-261М	dia 750	190 to 600	7	5,100
Vertical two-spindle	621М	dia 1,000	63 to 1,000 and 100 to 1,600	10/14	6,400
	6А23	dia 1,400	40 to 250 and 63 to 400	14/20	12,700

TABLE 23 (continued)

Type	Model	Working surface of table, mm	Range of spindle speeds, rpm	Power of drive motor, kW	Net weight, kg approx.
Vertical two-spindle	6M23	dia 1,600	31.5 to 500 and 50 to 800	10, 13 or 22	12,000
Vertical three-spindle	6M23B	dia 1,500	25 to 400 and 50 to 800	10, 13 or 22	12,400
	6A25	dia 2,000	25 to 600	22	16,000

The higher range is obtained by changing the gearing ratio between shafts *III* and *IV* from $\frac{22}{26}$ to $\frac{26}{22}$.

All the table motions—longitudinal, cross and vertical—are driven from a separate motor (0.6 kW and 1,420 rpm), built into the knee, through the gearing $\frac{20}{73} \times \frac{27}{69}$ and further, either through the feed gear train or through the rapid traverse gear train. The feed gear train includes: a 12-speed gearbox, any one of three engagements between shafts *X* and *XI* $\left(\frac{37}{53} \text{ or } \frac{30}{60} \text{ or } \frac{45}{45}\right)$, either of two engagements between shafts *XI* and *XII* $\left(\frac{24}{66} \text{ or } \frac{45}{45}\right)$, and two alternate engagements, one through the countergearing $\frac{18}{72} \times \frac{30}{60}$ and the other bypassing this countergearing arrangement. Upon the engagement of jaw clutch C_2, gear $60T$ is shifted out of mesh with gear $30T$, and engages with shaft *XII*. Motion is transmitted further through spool (wide-face) gear $60T$ *into which a safety clutch is built and which is freely mounted on* shaft *XIII*. Upon the engagement of clutch C_3, shaft *XIII* and gear $34T$ begin to rotate. Through gear $40T$, gear $34T$ drives the shafts in the knee.

Rapid traverse movements are obtained by bypassing shafts *X*, *XI* and *XII*, the gear train being from gear $69T$ to gear $21T$ which is linked to shaft *XIII* by a friction clutch.

The longitudinal, cross and vertical feeds are engaged by means of clutches C_4, C_5 and C_6, respectively. Longitudinal feeds are reversed by means of the bevel-gear reversing unit on shaft *XVII*, cross and vertical feeds, by means of intermediate gear $39T$ in the spur-gear reversing unit.

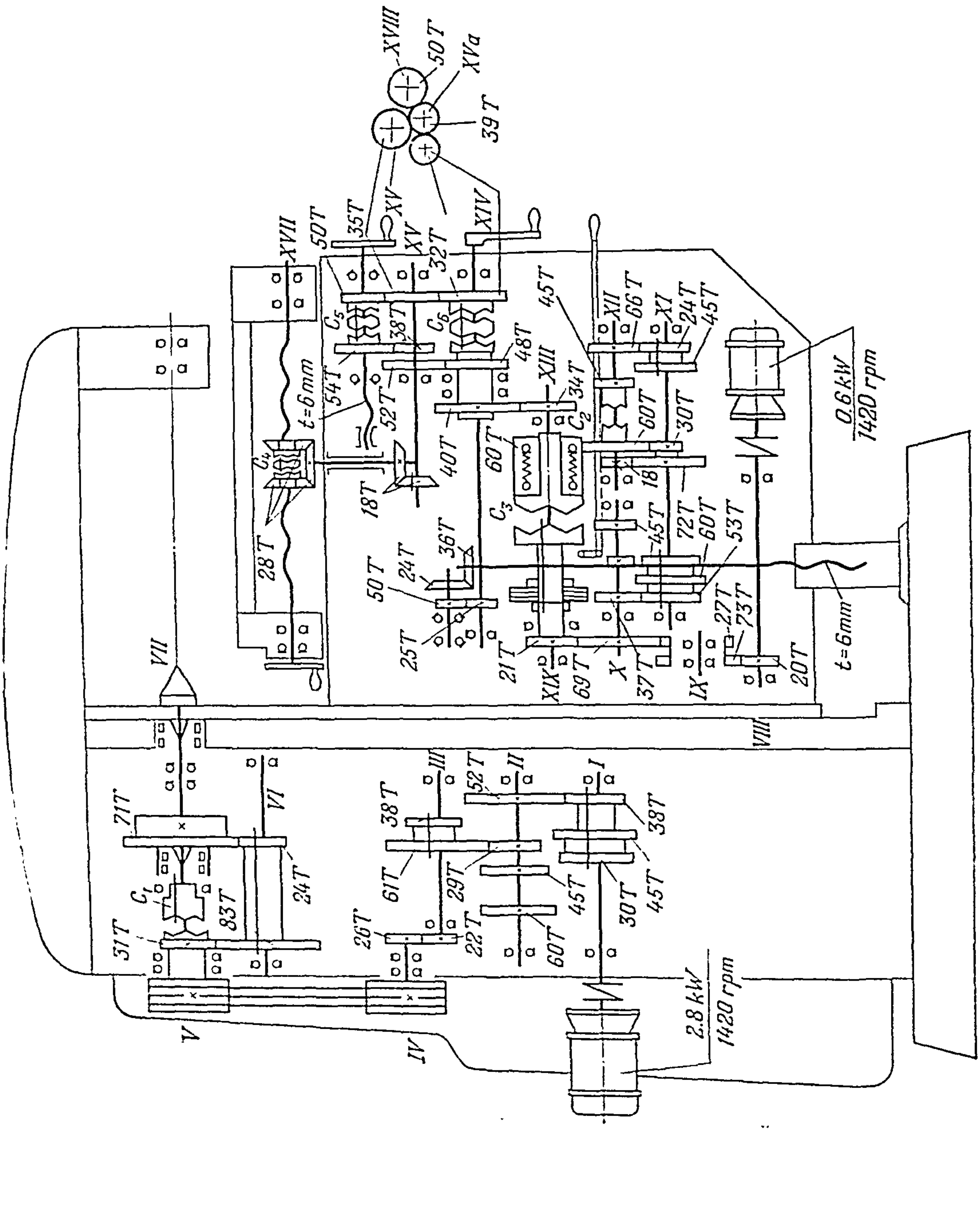


Fig. 147. Gearing diagram of the knee-type milling machines, models 6M80Γ and 6M80

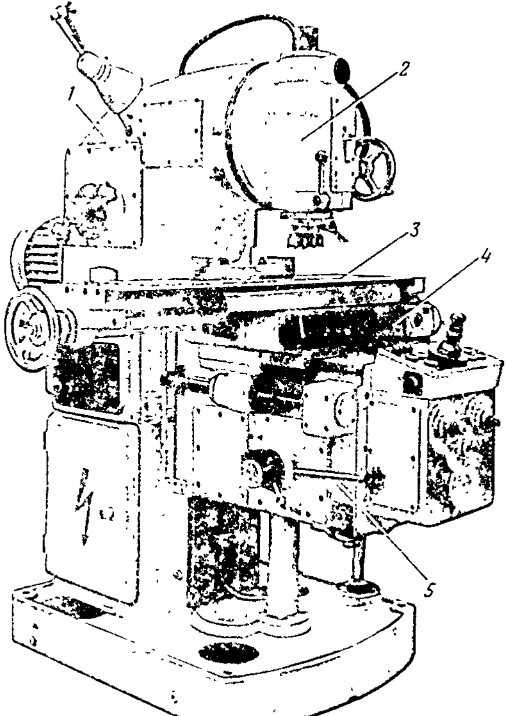


Fig. 148. Swivel-head vertical knee-type milling machine model 6M11B
1—column, 2—spindle head, 3—work table, 4—saddle, 5—knee

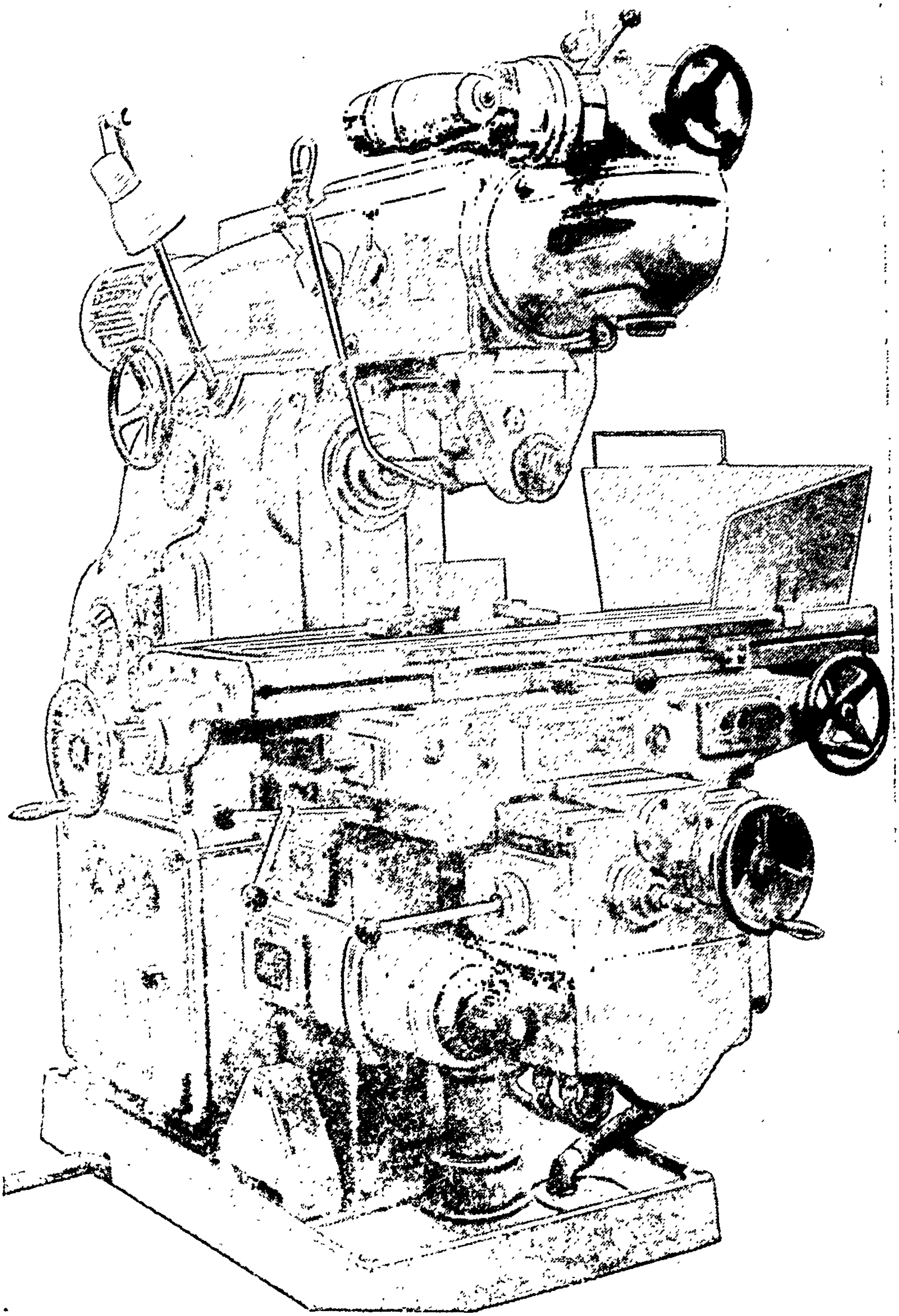


Fig. 149. Ram-head knee-type milling machine, model 6M82Ш

Plain horizontal milling machines are employed chiefly for machining ruled surfaces, including flat surfaces milled with plain and side milling cutters and contoured surfaces milled with form cutters. In repair shops, spur gears are cut frequently with gear milling cutters. Jobs requiring face milling cutters and end mills can also be performed.

Universal horizontal milling machines closely resemble the plain type. They also have a horizontal spindle, but the table can be swivelled about a vertical axis in respect to the saddle. This extends the processing capacities of the machine since the table can travel, not only perpendicular or parallel to the spindle axis, but also at an angle. This feature enables the machine to mill helical grooves, for instance the flutes of twist drills, and to cut helical gears.

Vertical knee-type milling machines, as their name implies, have a vertical spindle. They may be of the fixed-head, sliding-head, swivel-head type or a combination of the last two (Fig. 148). The vertical machines have neither overarm nor braces. All the other units are substantially the same as in the horizontal models. Vertical milling machines are most frequently tooled with face milling cutters and end mills.

Ram-head milling machines differ from the universal type in that they have an additional spindle head, mounted on a movable ram atop the column, that resembles the conventional overarm (Fig. 149). The spindle head can be swivelled about both vertical and horizontal axes so that the spindle can be disposed horizontally, vertically, or angularly. Some models have two spindles, horizontal and vertical, and a knee which can be swivelled with the work table about a horizontal axis perpendicular to the column face. Such millers are called compound universal by some manufacturers and omniversal milling machines by others In all cases, the spindle can be set at any angle to the work. These machines find wide application in experimental shops and toolrooms.

Another modification of the knee-type models is the high-speed milling machines. They have a wider range of spindle speeds and are designed for machining light alloys. The Russian letter Б is added to the model designation of Soviet high-speed milling machines as, for example, 6M12ПБ (see Table 23).

Compound-Table Milling Machines

One of the class of bed-type milling machines the compound-table machine, has a table which travels only in two directions, the longitudinal and cross directions, in contrast to the tables of the knee-type machines Adjustments in the vertical direction are accomplished by the spindle head The rigidity of compound-table millers is higher than that of knee-type models but the former are less versatile in operation.

Depending upon the arrangement of the spindle axis, the compound-table machines are subdivided into vertical- and horizontal-spindle models. The latter have not as yet found wide application.

Modifications with swivelling spindle heads, with tracer-control mechanisms and with combination tables are available for the principal models of vertical-spindle compound-table machines. In addition to longitudinal and cross feeds, the combination-table models also have rotary feeds imparted to a built-in rotary table. The letter K is added to the designation of Soviet models incorporating this feature, for example, 654K, etc. (see Table 23).

Figure 150 illustrates the Soviet vertical-spindle compound-table milling machine, model 654. Its principal units are: bed *1*, column *2*, saddle *3*, table *4*, spindle head slide *5*, spindle head *6* and pendent control station *7*.

The spindle of model 656П of this type is powered by the 20-kW electric motor M_1 running at 1,420 rpm (Fig. 151), through the 18-stage speed gearbox (three engagements between shafts *II* and *III*, three between shafts *III* and *IV*, and two between shafts *IV* and *V*). The gears are shifted to make the various engagements by two-position, C_2 and C_4, and three-position, C_1 and C_3, plunger-type hydraulic control cylinders.* The appropriate ends are connected to the pump station through the control valve CV which can be turned to 18 different positions. Oil is delivered to control valve CV from pump P_1 through filter F_1 and unloading valve V_2 which disconnects the control cylinders from the pump station if the pressure of the oil drops below 5 or 6 kg per sq cm. The maximum pressure is limited by relief valve V_1 set for 16 to 18 kg per sq cm.

The speed gearbox with motor M_1 is mounted in the spindle head which can be traversed for adjustment in setting up by motor M_2 (2.8 kW, 1,420 rpm) along the column ways at a velocity of

$$v_v = 1,420 \frac{36}{39} \times \frac{2}{28} 8 = 750 \text{ mm per min}$$

The spindle is traversed by pressing one of the push buttons, SP. HEAD UP or SP. HEAD DOWN. This energizes solenoid Sd_1 of pilot Pt_1 which, in turn, shifts the spool of valve V_3 to the UNCLAMP position. At this, oil from pump P_1 is delivered through valve V_3 to the head end of the four spindle-head slide clamping cylinders C_{cl} (only two cylinders are shown in the diagram). The slide is released and limit switch LS_1 starts motor M_2.

If necessary, the spindle head can be swivelled up to 30° to either side of the vertical position by turning the square shank on the end of shaft *XXIII*

*The operation of three-position cylinders is described in Part Four, Vol. 2.

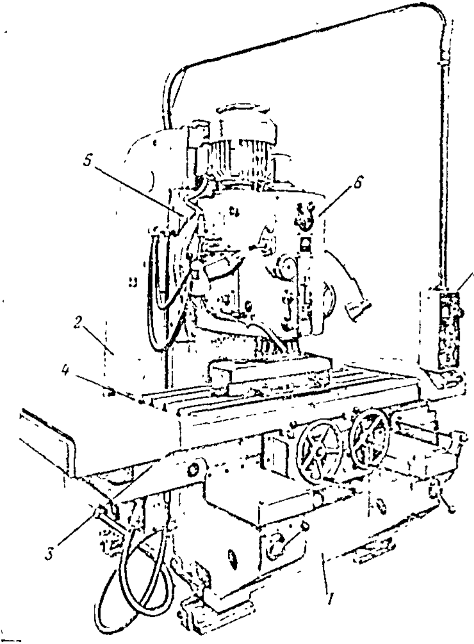


Fig. 150. Vertical-spindle compound-table milling machine, model 654

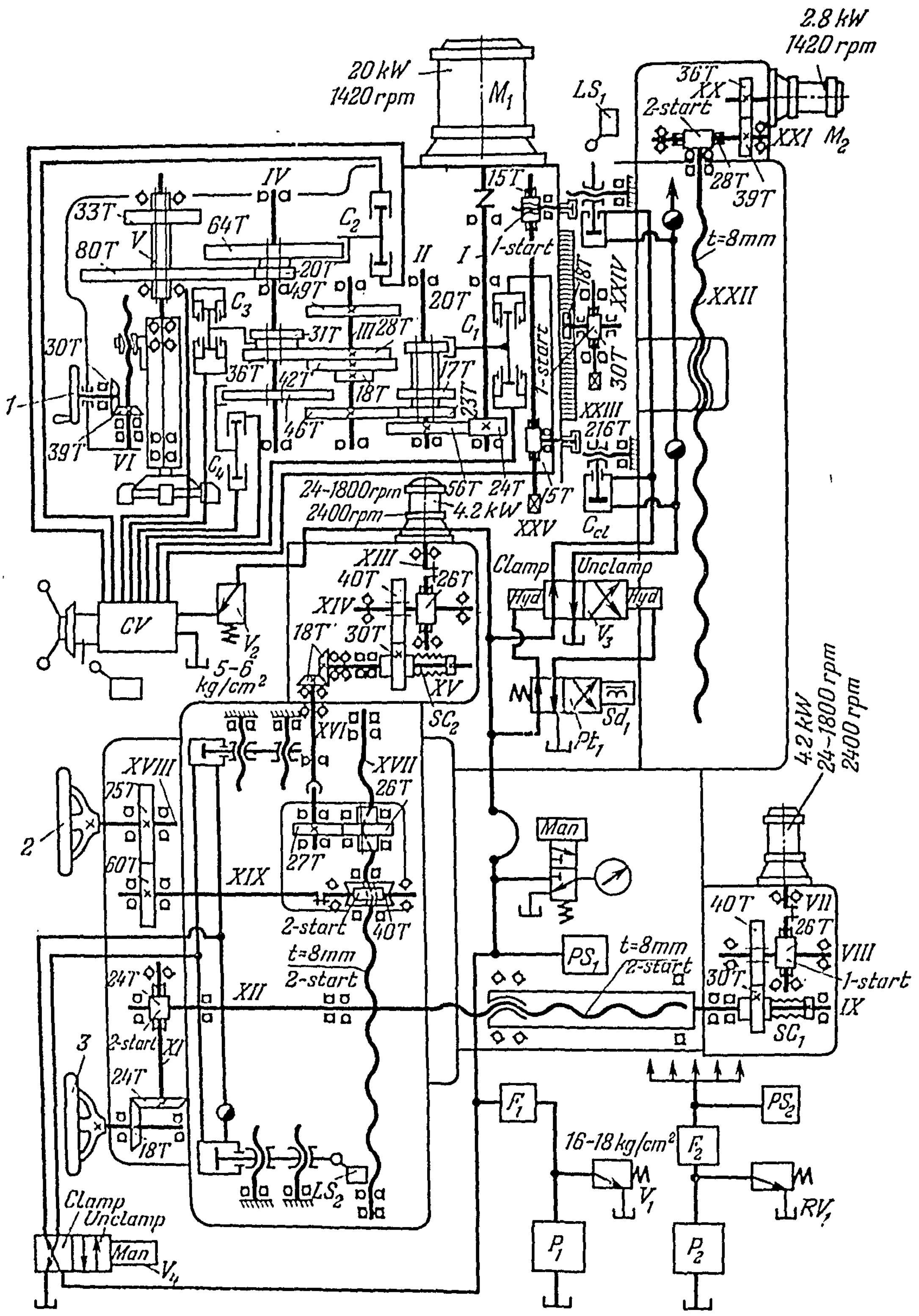


Fig. 151. Gearing diagram of the model 656П milling machine

by hand. Upon one revolution of this shaft, the spindle head swivels through one degree. Thus

$$\alpha = 1 \times \frac{1}{30} \times \frac{18}{210} 360^\circ = 1^\circ$$

Before swivelling the head it is necessary to release its clamps by turning the square shank of shaft *XXV*. The spindle quill is extended from and retracted into the head by turning handwheel *1*.

Longitudinal and cross working feeds are powered from separate d-c motors having infinitely variable speeds in the range from 24 to 1,800 rpm. Rapid traverse movements are obtained from the same motors which run at a speed of 2,400 rpm for this purpose. As is evident from the diagram, the following rates of feed and rapid traverse speeds are available for longitudinal (s_{lg}) and cross (s_{cr}) travel:

$$s_{lg} = (24 \ldots 1{,}800;\ 2{,}400) \frac{1}{26} \times \frac{40}{30} \times \frac{18}{18} \times \frac{27}{26} 8 \times 2 \cong$$

$$\cong 20 \ldots 1{,}500;\ 2{,}000 \text{ mm per min}$$

$$s_{cr} = (24 \ldots 1{,}800;\ 2{,}400) \frac{1}{26} \times \frac{40}{30} 8 \times 2 \cong 20 \ldots 1{,}500;\ 2{,}000 \text{ mm per min}$$

In longitudinal travel, screw *XVII* is rotated by gear $26T$; in cross travel, the nut of lead screw *XII* is rotated.

The cross travel motor can be switched on only after turning the handle of valve V_3 to the UNCLAMP position. This admits oil to the head end of the hydraulic saddle clamping cylinders and releases the saddle. Limit switch LS_2 is operated by the unclamping of the saddle; it prepares the circuit for starting the cross travel motor. Safety clutches SC_1 and SC_2, mounted on shafts *IX* and *XV*, begin to slip in case of an overload and thereby prevent breakage of the mechanism.

Manual traverse of the table in the longitudinal and cross directions is entirely independent of power feed and traverse. In hand longitudinal traverse, rotation of handwheel *2* is transmitted through the gearing $\frac{75}{60} \times \frac{2}{40} = \frac{1}{16}$ to the nut of lead screw *XVII*; in cross traverse, rotation is transmitted from handwheel *3* through the gearing $\frac{18}{24} \times \frac{2}{24} = \frac{1}{16}$ to lead screw *XII*.

The pressure switch PS_1 of the hydraulic control system switches off the spindle drive motor if the oil pressure in the system drops below 15 or 16 kg per sq cm.

Soviet mineral oil, grade Industrial 20, is employed as the working fluid in the hydraulic control system.

The centralized lubricating system is separate from the hydraulic system. It includes pump P_2, relief valve RV_1, filter F_2 and pressure switch PS_2

The latter permits spindle rotation to be switched on only when there is sufficient oil pressure in the lubricating system. Mineral oil, grade Industrial 45, is used as the lubricant in the system.

Compound-table milling machines are extensively employed for the high-velocity milling of flat surfaces with large machining allowances on housing-type parts. The machines can be set up for an automatic operating cycle, comprising the elements: working feed, rapid return and stop. In some models of this type the cutter is automatically withdrawn from the work during the return traverse of the table to avoid damaging the machined surface.

Fixed-Bed and Planer-Type Milling Machines

In these machines the table can travel in only one direction—longitudinally. All vertical and cross movements are imparted to the milling heads and the spindles.

Planer-type milling machines may be of openside (single-housing) design (Fig. 152) or of double-housing design (Fig. 153). The fixed-bed models are designated as "simplex", having a single spindle, and "duplex", having a spindle on each side of the table. The size of the table in the Soviet machines

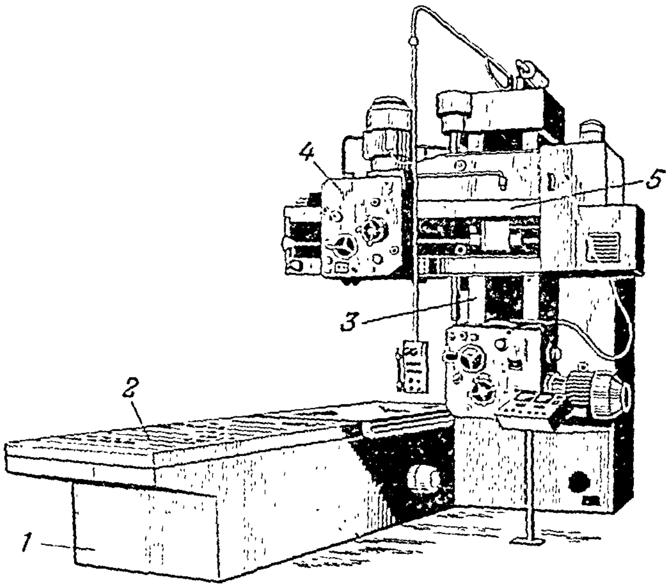


Fig. 152. Openside planer-type milling machine, model 6641:
1—bed; 2—table; 3—housing; 4—milling head; 5—crossrail

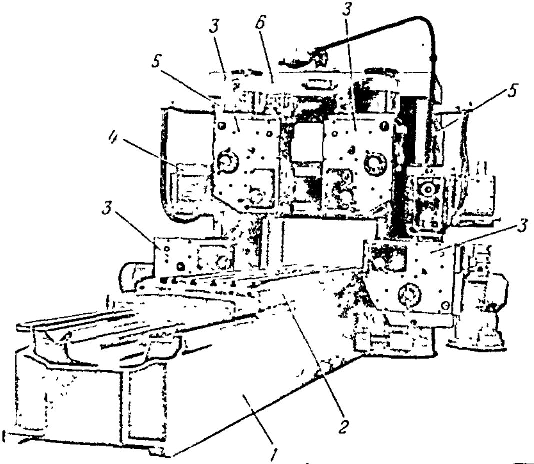


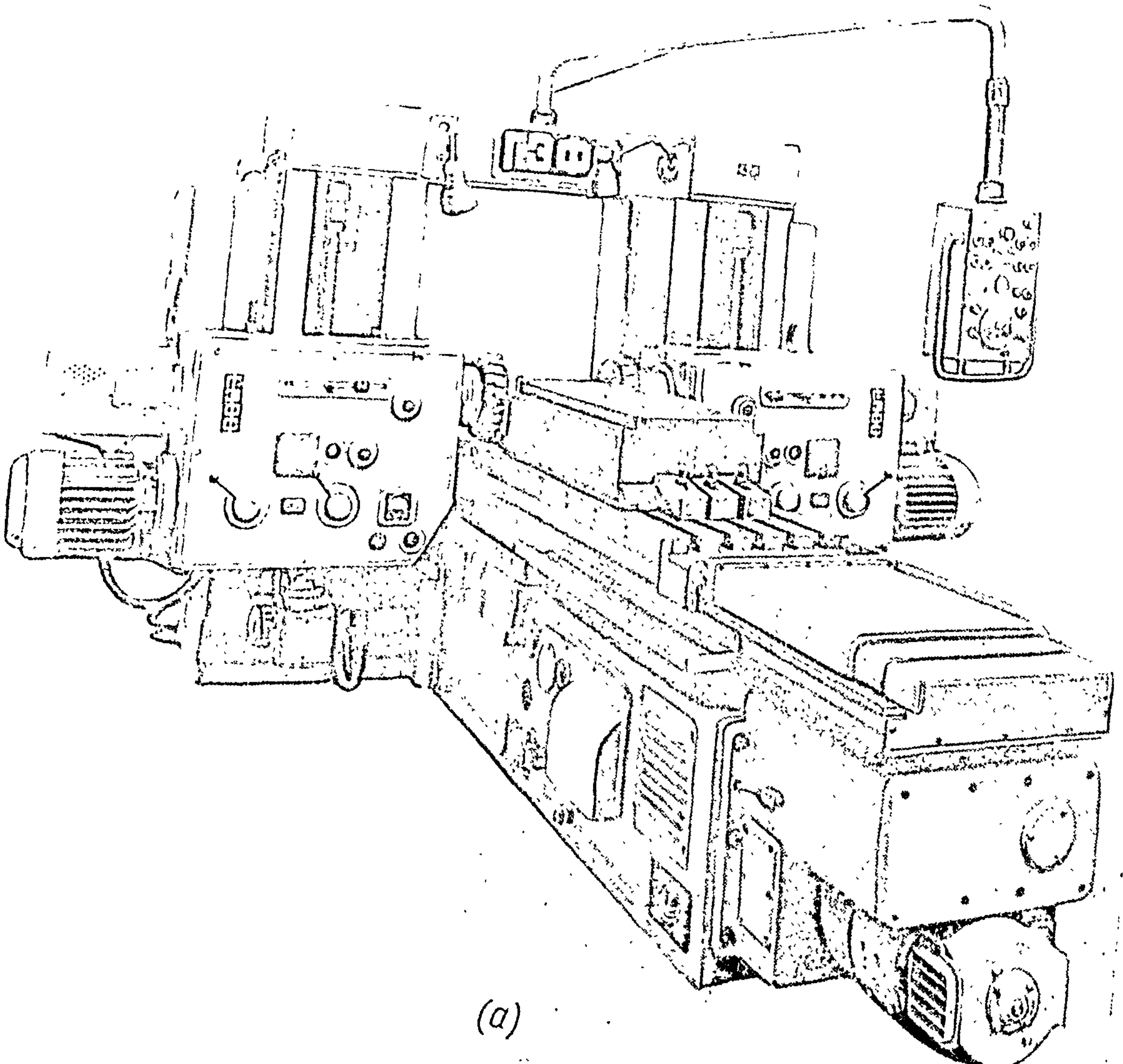
Fig. 153 Double-housing planer-type milling machine, model 6610, with two vertical and two horizontal spindles.

1—bed, 2—table, 3—milling head, 4—crossrail, 5—housing, 6—cross-stay

ranges from $320 \times 1{,}000$ mm to $4{,}000 \times 12{,}000$ mm (modls 6303 and 6640, respectively, see Table 23)

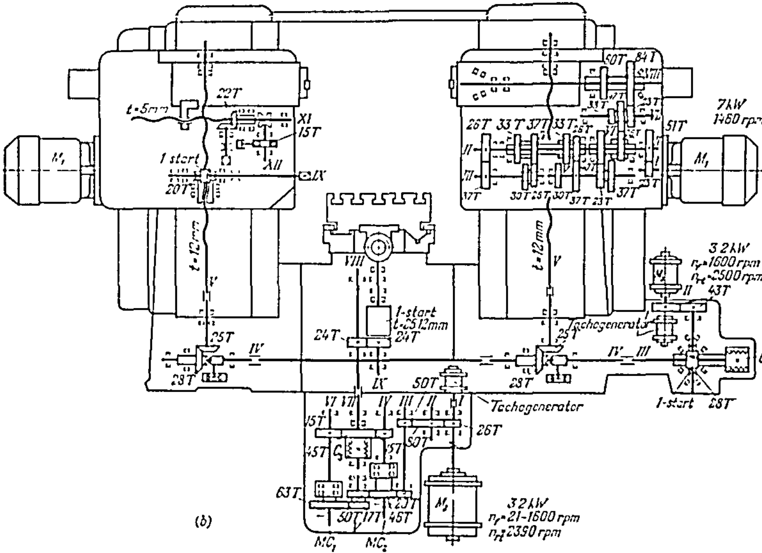
Milling heads with horizontal spindles are disposed on each housing, while the planer-type machines have a crossrail along which milling heads with vertical spindles travel.

In setting up these machines, the heads with the horizontal spindles can be adjusted up or down along the housings; the heads with vertical spindles can be adjusted to the right or left along the crossrail and up or down together

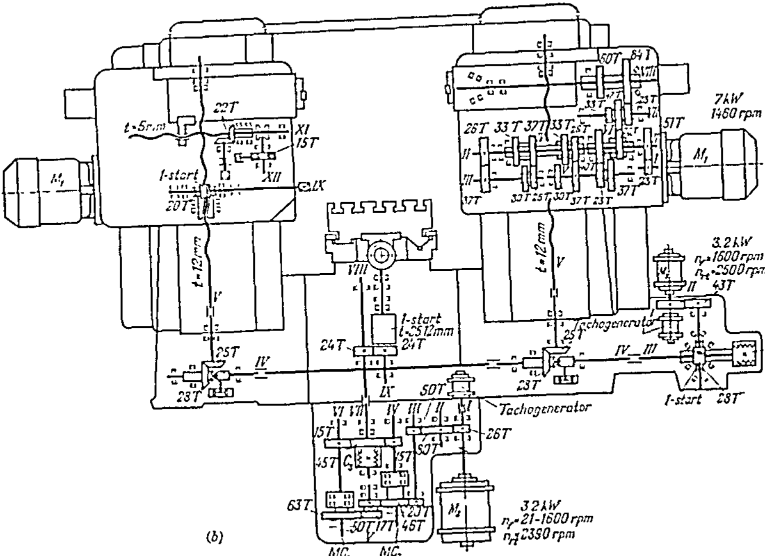


(a)

Fig. 154. Fixed-bed horizontal duplex milling machine, model 6605:
(a) general view; (b) gearing diagram



(b)


7 kW
1460 rpm
3.2 kW
Tachogenerator
1-start
t=12 mm
t=5 mm
1-start
t=25.12 mm
3.2 kW
n_r=21-1600 rpm
n_H=2390 rpm
M_1
M_2
C_4
MC_1
MC_2

(b)

with the crossrail. These are all power traverse movements. Besides, each spindle can be extended from its head and, in many models, the milling heads can be swivelled to either side of the middle position through an angle up to 30°.

Both plain and face milling cutters are used on planer-type milling machines; horizontal and vertical flat surfaces on various kinds of workpieces are machined (chiefly in lot and mass production).

Figure 154 illustrates the general view and gearing diagram of the model 6605 fixed-bed horizontal duplex milling machine. It is a typical duplex model with two horizontal-spindle milling heads and without a crossrail.

Sixteen different speeds of rotation are transmitted to the spindles along the following gear train: motor M_1 (7 kW, 1,460 rpm), gearing $\frac{23}{51} \times \frac{26}{37}$, double cluster gear providing the engagement $\frac{26}{37}$ or $\frac{30}{33}$ between shafts *III* and *IV*, double cluster gear on shaft *IV* transmitting rotation to shaft *V* through gears $\frac{26}{37}$ or $\frac{33}{30}$, and a double cluster gear $\frac{23}{40}$ or $\frac{37}{26}$ between shafts *V* and *VI*. From shaft *VI* rotation is transmitted further through shaft *VII* to shaft *VIII* (spindle) through the gears $\frac{26}{47} \times \frac{23}{84}$ or $\frac{40}{33} \times \frac{47}{60}$.

Longitudinal travel of the table is obtained when the electromagnetic feed clutch MC_1 is engaged through a rack-and-worm drive. This drive is powered by d-c motor M_2 whose speeds can be steplessly varied in the range from 21 to 1,600 rpm. Therefore, working feeds can be obtained in the following range:

$$s_{lg} \quad (21 \ldots 1{,}600) \frac{26}{80} \times \frac{80}{50} \times \frac{20}{46} \times \frac{46}{50} \times \frac{17}{63} \times \frac{15}{45} \times \frac{24}{24} 25.12 \cong$$

$$\cong (10 \ldots 750) \text{ mm per min}$$

Rapid traverse movements of the table are powered from the same electric motor, but running at 2,390 rpm, through a shorter gear train. Rapid traverse is obtained when clutch MC_1 is disengaged and electromagnetic rapid traverse clutch MC_2 is engaged. Then

$$s_{rt} \quad 2{,}390 \frac{26}{80} \times \frac{80}{50} \times \frac{20}{46} \times \frac{15}{45} \times \frac{24}{24} 25.12 = 4{,}500 \text{ mm per min}$$

Vertical traverse of the milling heads is powered by d-c motor M_3 which runs at two speeds. The rates of traverse are

$$s_v = (1{,}600;\ 2{,}500) \frac{43}{43} \times \frac{1}{28} \times \frac{28}{25} 12 = (768;\ 1{,}200) \text{ mm per min}$$

Clutches C_3 and C_4 serve to protect the corresponding gear trains against overloads.

Rotary-Table Milling Machines

The table of these machines has only rotary feed. In setting up the machine the table can be traversed along the ways of the bed crosswise toward the column, and the spindle head can be adjusted up or down along the vertical ways of the column. In addition, the spindle can be extended from or retracted into the spindle head.

Rotary-table milling machines are produced in the USSR in a size range with table diameters from 750 to 2,000 mm. Both horizontal- and vertical-spindle models are available (see Table 23). Most widely employed of these millers are the models with one or more (two or three) vertical spindles. In the multiple-spindle machines one of the spindles is used for finish milling. Special rotary-table machines may have even more spindles. Double-sided rotary-table millers with two housings are also manufactured.

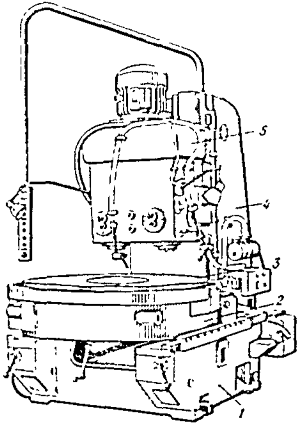


Fig. 155. Two-spindle vertical rotary-table milling machine, model 6A23

The blank is clamped in a fixture on the rotating table of this type of machine and it passes under one or more milling cutters, depending upon the construction of the miller. The work is loaded and unloaded without stopping the table so that milling proceeds continuously. The output is consequently very high and such machines are chiefly used in mass production. However, if several different fixtures are mounted simultaneously on the table, the machines can be efficiently employed in lot production to mill several different workpieces, or different surfaces on identical workpieces.

A two-spindle rotary-table milling machine of Soviet design is shown in Fig. 155. Its principal units are: bed *1*, rotary table *3* with saddle *2*, column *4*, and spindle head *5* with the drive. The two spindles are driven by the same motor but can operate at different speeds. The right spindle, designed for roughing operations, has a range from 40 to 250 rpm. The range of the left spindle for finishing is from 63 to 400 rpm. Frequently, the designs of these machines are unified with those of compound-table milling machines.

The rotary feed of the table is powered from a separate motor through a feed gearbox with change gears. The required number of teeth of the change gears can be determined from the equation

$$s_r = n_m i \pi D \text{ mm per min}$$

where n_m = speed of the motor, rpm

i = gearing ratio of the gear train from the motor to the table

D = effective diameter of the table, mm; depending upon the arrangement of the fixtures, diameter D may be taken as the outside diameter of the table or $^1/_2$ or $^2/_3$ of this diameter.

8-3. Attachments Extending the Processing Capacities of General-Purpose Milling Machines

1. *Dividing heads* are used in milling various flutes, slots, grooves, gashes, etc., which must be equally spaced about the circumference of the work (and, less frequently, unequally spaced) and arranged either parallel to or at an angle to the axis of the work. Such jobs may include the milling of spur and helical gears, spline shafts, twist drills, reamers, milling cutters, etc.

There are plain, universal and optical dividing heads. The universal heads are available in two designs: with and without an index plate.

Plain dividing heads are used for direct indexing (dividing) a circumference into a comparatively small number of parts (Fig. 156). Heads of this type have an indexing plate with a definite number of slots or holes mounted on the spindle of the head. The plates may be interchangeable. The spindle is turned for indexing by hand together with the plate. Such heads may

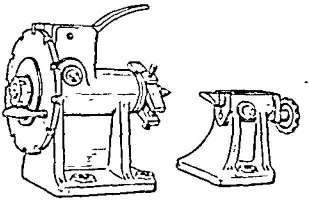


Fig. 156. Plain dividing head

have either horizontal or vertical spindles; they may be of the single- or multiple-spindle type. Multiple-spindle heads are used for simultaneously indexing several workpieces.

Optical dividing heads (Fig. 157) are used for precise measurement of angles in manufacturing various parts, and also for inscribing circular scales.

Provision is made in optical heads for direct indexing. For this purpose, single-start worm *9* is disengaged, by turning eccentric sleeve *8*, from worm wheel *7* having 40 teeth. After this, spindle *6* can be turned directly by hand and the angle of rotation can be read off on the scale of disk *5* mounted on the spindle. The scale has one-degree divisions.

To obtain precise readings the worm is engaged with the worm wheel. The spindle is now rotated by coarse-setting handwheel *10* and fine-adjustment head *11*. The angle of spindle rotation is read off by means of the optical system with an accuracy within 20". The optical system includes the illuminating lamp *2*, reflecting plate *3* on which a scale with 60 divisions is engraved for reading minutes, glass disk *4* with 360 divisions for reading off whole degrees, and microscope *1*.

The spindle of the head can be tilted to any angle up to the vertical with an accuracy within 6' and clamped in position with handle *12*.

Universal dividing heads (Fig. 158) can be set up for direct, simple or differential indexing, or for milling helical grooves, depending upon the job to be performed and the complexity of the required indexing.

Universal dividing heads are set up for direct indexing in the same way as optical heads, i.e., by disengaging the worm from the worm wheel. Then indexing is accomplished by turning the spindle with the work by hand

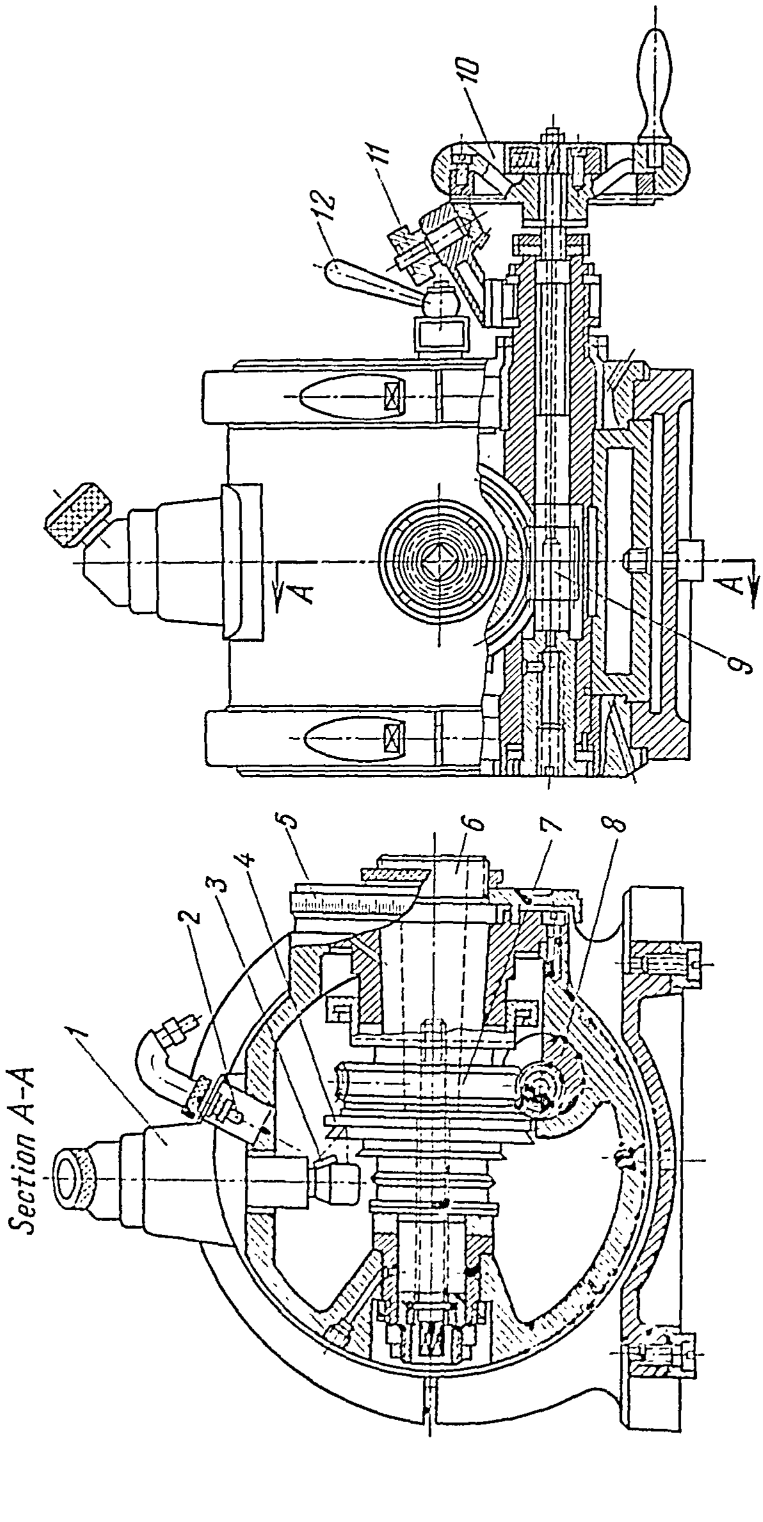


Fig. 157. Optical dividing head

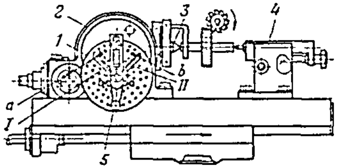


Fig. 158. Universal dividing head:
1—index plate; 2—housing; 3—spindle, 4—tailstock, 5—index crank

through the required angle each time. In this case, the head must have, mounted on the spindle, either a front plate with holes for an index pin, or a disk with a scale in degrees.

In dividing heads of up-to-date design, such as Soviet models И-135, И-160 and И-100, readings are made on the direct-indexing scale, divided into degrees, and the vernier which enables angles to be read to an accuracy of 5'. The angle of spindle rotation is determined in this case by the equation

$$\alpha = \frac{360°}{z}$$

where $\alpha°$ = required angle of spindle rotation
z = required number of divisions.

Setting up the head for simple indexing. In this case worm z_w is engaged with worm wheel W, and index plate I (Fig. 159 above) or gear z_1 of the differential, on heads without index plates (Fig. 159 below), is fixed in a stationary position. To rotate the spindle $\frac{1}{z}$ part of the circumference, it is necessary to turn the worm through n' revolutions, determined from the formula

$$n' = \frac{N}{z}$$

where N is the ratio of the number of teeth on the worm wheel to the number of starts on the worm, called the *ratio* of the head.

In modern dividing heads, N is usually 40; there are heads, however, in which N equals 60 or 80 or even 120.

In the index plate heads, index crank 2 is linked to worm z_w through gears with a total gearing ratio of 1 : 1. Therefore, to turn the worm through n'

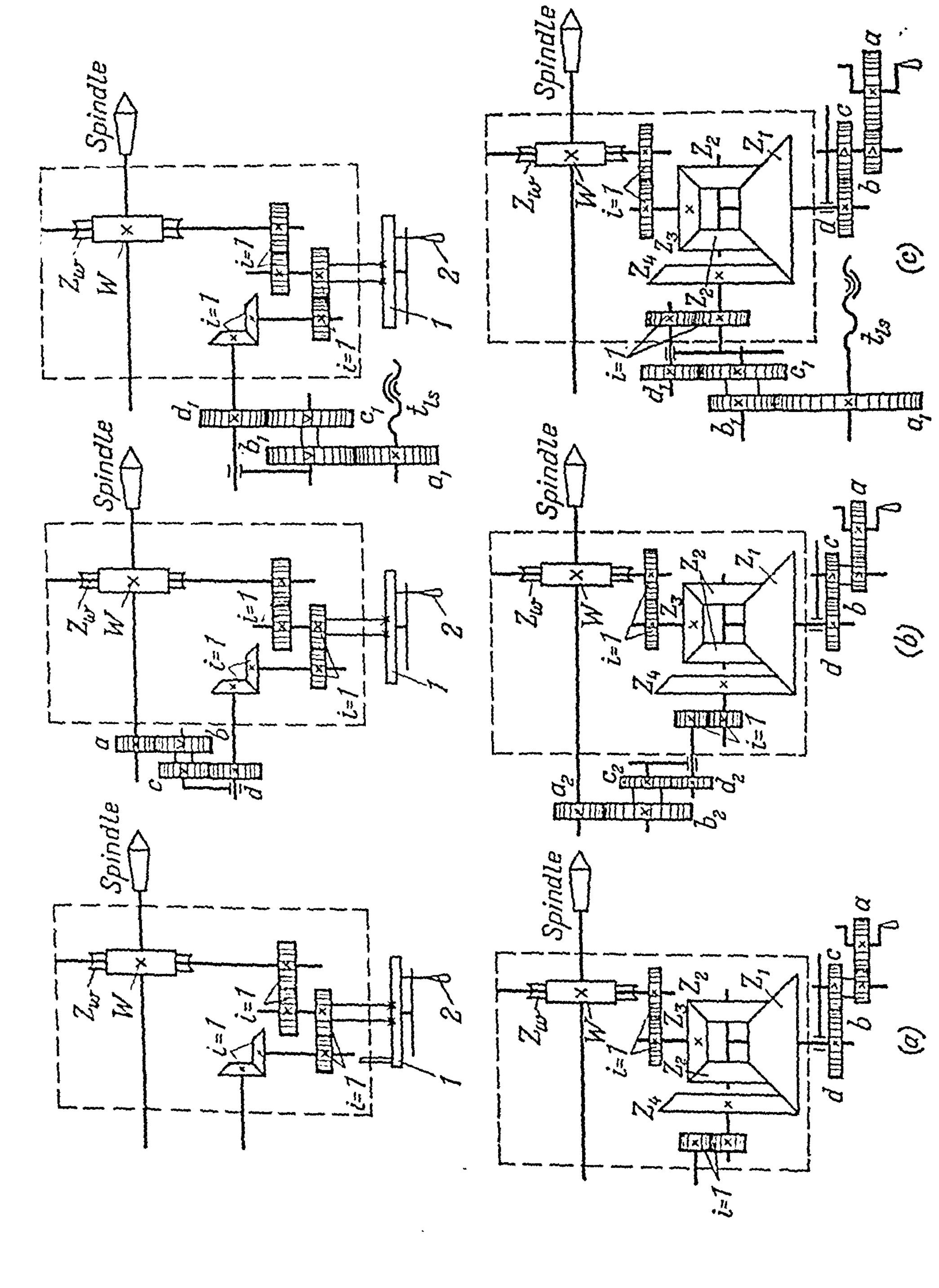


Fig. 159. Gearing diagrams of dividing heads with and without an index plate

revolutions, it will be necessary to turn index crank 2 through n revolutions where

$$n = n' = \frac{N}{z}$$

In most cases, $n \neq E$, where E is the symbol for an arbitrary whole number. Therefore, it will be necessary to select a whole number B, such that $\frac{N}{z}B = E$. Thus

$$n = \frac{\frac{N}{z}B}{B} = \frac{E}{B} \tag{13}$$

If $E > B$ we can write

$$n = C + \frac{A}{B} \tag{14}$$

where C = number of whole turns of index crank 2
B = number of holes in the selected hole circle of the index plate
A = number of spaces in the selected hole circle of the index plate the index pin must pass over in addition to C whole turns of the crank.

Indexing heads, models H-135 and H-160, have index plates with blind holes on each side. On one side they have 16, 17, 19, 21, 23, 29, 30 and 31 hole circles, and on the other side they have 33, 37, 39, 41, 43, 47, 49 and 54 hole circles.

The adjustable sector (see Fig. 158) is used for convenience in counting the number of spaces A on the selected hole circle B. The sector fingers I and II are set to an angle corresponding to the required number of spaces and then the rings are tightened with the lock screw. Before beginning the indexing operation, the sector is swivelled to bring sector finger I up against the pin of the index crank, located in one of the holes of hole circle B, for example, hole a. Then sector finger II will be to the right (outer) side of hole b into which the index pin is to be relocated after indexing. After placing the pin into hole b swivel the sector once more in the same direction until sector finger I is brought up against the pin again. Then sector finger II will indicate the hole into which the pin must be relocated for the next indexing, etc.

In the indexing heads without plates (Fig. 159 below), the index crank for rotating the spindle is linked to the worm through a gear train consisting of a differential and indexing change gears $\frac{a}{b} \times \frac{c}{d}$. This gear train is set up so that the required number of revolutions of the worm (and the consequent angle of spindle rotation) is obtained by turning the index crank a whole number of turns, most frequently one full turn. Thus, the gear

train must comply with the following equation:

$$n' = n\frac{a}{b} \times \frac{c}{d} i_{diff} i$$

where n = number of index crank revolutions
a, b, c and d = number of teeth on the indexing change gears
i_{diff} = gearing ratio of the differential (when gear z_1 is fixed, $i_{diff} = 2$)
i = gearing ratio between the differential and the worm ($i = 1$).

Thus after making the substitution $n' = \frac{N}{z}$ we can write the formula for calculating the indexing change gears

$$\frac{a}{b} \times \frac{c}{d} = \frac{N}{2zn} \tag{15}$$

In addition to the described method of simple indexing, another method involves indexing with a certain constant skipping instead of the ordinary consecutive procedure, i.e., the spindle of the head is rotated in each indexing operation through a $\frac{p}{z}$ part of a circle instead of a $\frac{1}{z}$ part. In this case, the number p of skips must have no common factors with the given number of divisions z. This method is especially useful in cases when the dividing head cannot be set up by the method described above. In these cases, it will be the only method that can be employed if helical grooves are to be milled or if the spindle of the head is to be tilted as in cutting the teeth of a bevel gear.

If the condition implied by equation (13) cannot be complied with due to the inavailability of an index plate with a hole circle having B holes (in this type of head, of course), any hole circle is selected with the largest number of holes B', and the value p (not a multiple of z) is selected so that the numerator of the fraction

$$n'_p = \frac{\frac{N}{z} B' p}{B'} \simeq n_p = \frac{A'}{B'} \tag{16}$$

is as close as possible to a whole number, to which it is rounded off. The obtained relationship is then transformed, as described previously, according to equation (14).

In setting up a dividing head without an index plate for simple indexing with skipping, the values of p and n are modified, selecting a ratio i_{ind} for the indexing change gears which differs from the required value by the least possible amount. Thus

$$\frac{Np}{2zn} \simeq \frac{a}{b} \times \frac{c}{d} = i_{ind} \tag{17}$$

The accumulated error on the last pitch indexed for a workpiece of a radius R, due to the indicated rounding off, is determined from the equations:

$$\Delta = \left(\frac{n_p}{p} - \frac{N}{z}\right)\frac{2\pi Rz}{N} \tag{18}$$

for dividing heads with index plates

$$\Delta = \left(\frac{2n i_{ind}}{p} - \frac{N}{z}\right)\frac{2\pi Rz}{N} \tag{19}$$

for dividing heads without index plates.

The error Δ may be either positive or negative.

Differential indexing is employed in cases when a circumference cannot be divided as required by direct or simple indexing, and the method of approximate simple indexing does not provide sufficient accuracy.

In differential indexing the worm is engaged with the worm wheel, and index plate *1* or gear z_1, on heads without index plates, must be linked to the spindle of the head through a gear train consisting of the differential quadrant with change gears a, b, c and d in the heads with index plates (Fig. 159*b* above) and with change gears a_2, b_2, c_2 and d_2 in the other type of heads (Fig. 159*b* below) Since the spindle is thus linked by change gears to the drive shaft of the head, differential indexing is possible only with the spindle in the horizontal position.

The special feature of differential indexing is that the required rotation of the work is obtained as a result of the rotation of not only the index crank, but of index plate *1* or gear z_1 of the differential as well (Fig. 159*b*).

The number of turns of the index crank is determined in the same manner as for simple indexing by making use of formula (14) or (15). However, the formula is solved not for the required number of divisions z, but for another number z_x, near to the required value, and one for which a hole circle can be selected on the available index plates, or change gears can be selected for the indexing quadrant of heads without index plates. The error of such a setup is compensated for by setting up the differential quadrant whose gearing ratio i_{dq} is determined (for both types of heads) by the formula

$$i_{dq} = \frac{N}{z_x}(z_x - z)$$

The gearing ratio i_{dq} may be either positive or negative If i_{dq} is positive, the direction of rotation of the index plate should coincide with the direction of the index crank (clockwise) while gear z_1 of the differential in the other type of head should rotate in the opposite direction If, on the other hand, i_{dq} is negative and the index crank is rotated clockwise, the index plate must rotate in the opposite direction (counterclockwise) and gear z_1 in

train must comply with the following equation:

$$n' = n\frac{a}{b} \times \frac{c}{d} i_{dif} i$$

where n = number of index crank revolutions
a, b, c and d = number of teeth on the indexing change gears
i_{dif} = gearing ratio of the differential (when gear z_1 is fixed, $i_{dif} = 2$)
i = gearing ratio between the differential and the worm ($i = 1$).

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$$n'_p = \frac{\frac{N}{z} B'p}{B'} \cong n_p = \frac{A'}{B'} \tag{16}$$

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The special feature of differential indexing is that the required rotation of the work is obtained as a result of the rotation of not only the index crank, but of index plate *1* or gear z_1 of the differential as well (Fig. 159*b*).

The number of turns of the index crank is determined in the same manner as for simple indexing by making use of formula (14) or (15). However, the formula is solved not for the required number of divisions z, but for another number z_x, near to the required value, and one for which a hole circle can be selected on the available index plates, or change gears can be selected for the indexing quadrant of heads without index plates. The error of such a setup is compensated for by setting up the differential quadrant whose gearing ratio i_{dq} is determined (for both types of heads) by the formula

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The gearing ratio i_{dq} may be either positive or negative. If i_{dq} is positive, the direction of rotation of the index plate should coincide with the direction of the index crank (clockwise) while gear z_1 of the differential in the other type of head should rotate in the opposite direction. If, on the other hand, i_{dq} is negative and the index crank is rotated clockwise, the index plate must rotate in the opposite direction (counterclockwise) and gear z_1 in

the same direction as the crank (clockwise). The required direction of rotation of the index plate or of gear z_1, as here indicated, is obtained by introducing an intermediate gear, if required, into the differential quadrant.

Dividing heads, models H-135 and H-160, are furnished with change gears having the following number of teeth: 25, 25, 30, 35, 40, 50, 55, 60, 70, 80, 90 and 100.

Setting up a universal dividing head for milling helical grooves involves: setting up the head for simple indexing to the number of starts of the helical grooves (or number of flutes, etc.); setting up the change gear quadrant for helical milling, and swivelling the work table to the helix angle of the grooves or flutes so that the central plane of a disk-type cutter coincides with the direction of the helical groove. It is not necessary to swivel the table if an end-mill type cutter is used.

The helical motion of the work required to mill the groove is composed of two simple motions—rotation of the blank about its axis and travel along this axis. The ratio of these two motions should be such that in one revolution of the blank it travels axially a distance equal to the lead of the helical groove to be milled. This ratio is obtained by setting up the gear train which links the lead screw for longitudinal table travel to the spindle of the head. In heads with index plates this gear train includes the following elements (see Fig. 159*c*): lead screw t_{ls}, screw-cutting quadrant $y = \frac{a_1}{b_1} \times \frac{c_1}{d_1}$, constant bevel and spur gearing with $i = 1$, index plate *1*, index crank *2*, worm gearing $\frac{z_w}{W} = \frac{1}{N}$, and the spindle. The elements of the other type of heads are: lead screw t_{ls}, screw-cutting quadrant $y = \frac{a_1}{b_1} \times \frac{c_1}{d_1}$, spur gearing with $i = 1$, bevel gearing $\frac{z_4}{z_1} \times \frac{z_1}{z_2} \times \frac{z_2}{z_3} = 1$, spur gearing with $i = 1$, worm gearing $\frac{1}{N}$ and the spindle.

From the equations for these gear trains we can write the setting-up formula for the thread-cutting change-gear quadrant. It is identical for both types of heads

$$y = N \frac{t_{ls}}{t_{hg}} \tag{20}$$

where t_{hg} = lead of the helical groove

t_{ls} = lead of the longitudinal travel lead screw of the machine.

If the helical surface is specified by the helix angle β and the diameter D of the cylinder to which this angle is referred, the lead of the helix is found from the formula

$$t_{hg} = \frac{\pi D}{\tan \beta}$$

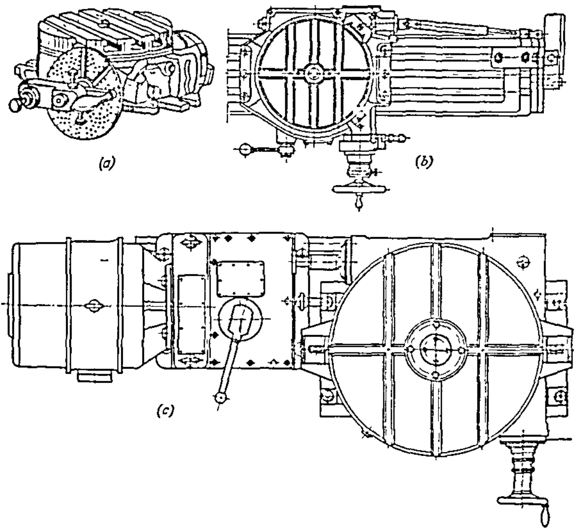


Fig. 160. Rotary table and circular milling attachments

As mentioned previously, if a disk-type cutter is used, it will be necessary to swivel the table through the angle β found from the equation

$$\beta = \arctan \frac{\pi D}{t_{hg}}$$

2. *Rotary tables and circular milling attachments* are used for milling flats on the work arranged at specified angles to each other, and also for continuous milling with circular feed.

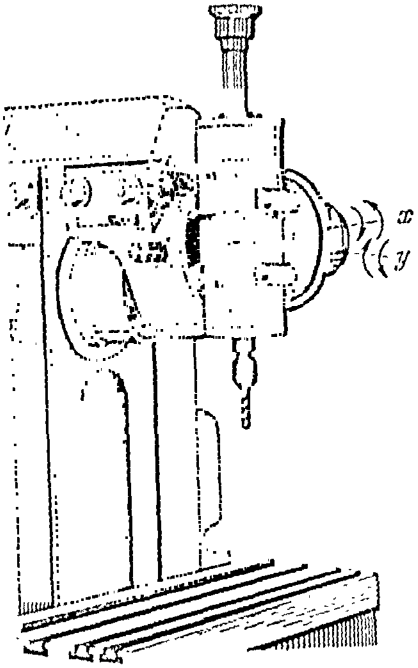


Fig. 161. Universal milling attachment

Rotary tables used for indexing purposes (Fig. 160) have a mechanism for fixing and clamping the table. The table is rotated by a crank handle through worm gearing and the angle of table rotation is read off on a circular scale on the periphery of the table, or indexing is accomplished with an index plate by the simple indexing method (Fig. 160*a*). The required number of turns of the crank handle, or index crank, is determined from the formula

$$n = \frac{N_t}{z}$$

where N_t = ratio of the rotary table (ratio of the number of teeth on the worm wheel to the number of starts on the worm)

z = number of divisions required.

If the table is to be rotated through a given angle between the surfaces being milled, the number of handle turns is determined from the formula

$$n = \frac{(180° - \beta)\, N_t}{360°}$$

where β is the angle between the surfaces to be milled, deg.

Circular milling attachments used for continuous milling are powered either from the feed gearbox through a drive rod of the longitudinal table, if such a table is available (Fig. 160*b*), or from an independent drive through a feed gearbox (Fig. 160*c*). Milling operations with continuous feed are performed in the same way as on a rotary-table milling machine.

3. *Universal milling attachments* (Fig. 161) are used on fixed-bed, and plain and universal horizontal milling machines for machining flat surfaces arranged at various angles. The attachment is mounted on the dovetail guides of the overarm and is driven by the spindle of the milling machine. The spindle of the attachment can be swivelled through 90° about axis y and 45° about axis x to either side of the vertical position. Such attachments are employed to mill various grooves, impressions of dies and other similar work when a ram-head milling machine is not available.

4. *Universal spiral milling attachments* (Fig. 162) are used for helical milling with a disk-type cutter on a plain horizontal machine, and also in milling with a large helix angle on a universal machine (if the helix angle

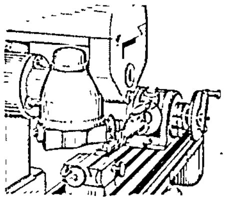


Fig. 162. Universal spiral milling attachment

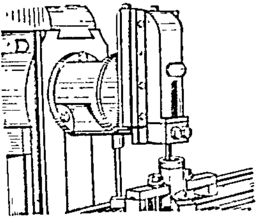


Fig. 163. Slotting attachment

exceeds the maximum angle of table swivel). The spindle of the attachment can be swivelled to any angle about the horizontal and vertical axes. The processing capacities of a plain horizontal milling machine are extended by this attachment to those of a universal horizontal miller. Installed on a universal miller, the attachment enables helical grooves with a helix angle over 45° to be milled. Such include the thread of worms, screws, etc.

5. A *slotting attachment* can be used for slotting keyways and contoured surfaces when a regular slotting machine is not available. The slotting attachment (Fig. 163) is mounted on the horizontal spindle of the milling machine and its housing is secured to the column or spindle head. The mechanism of the attachment converts rotation of the spindle into reciprocating motion of the sliding ram. Single-point slotting tools are clamped into one end of this ram. The sliding ram can be set at any angle up to 360° about the horizontal axis.

8-4. Single-Purpose Milling Machines

Single-purpose milling machines are designed for machining parts of a single type with different milling cutters. They can be changed over for the efficient machining of blanks for one size of parts to those of another size, and find application in lot and large-lot production.

The most widely employed single-purpose milling machines are: (a) tracer-controlled duplicating machines; (b) keyway millers, (c) circular sawing machines; (d) drum-type milling machines, (e) circular milling machines;

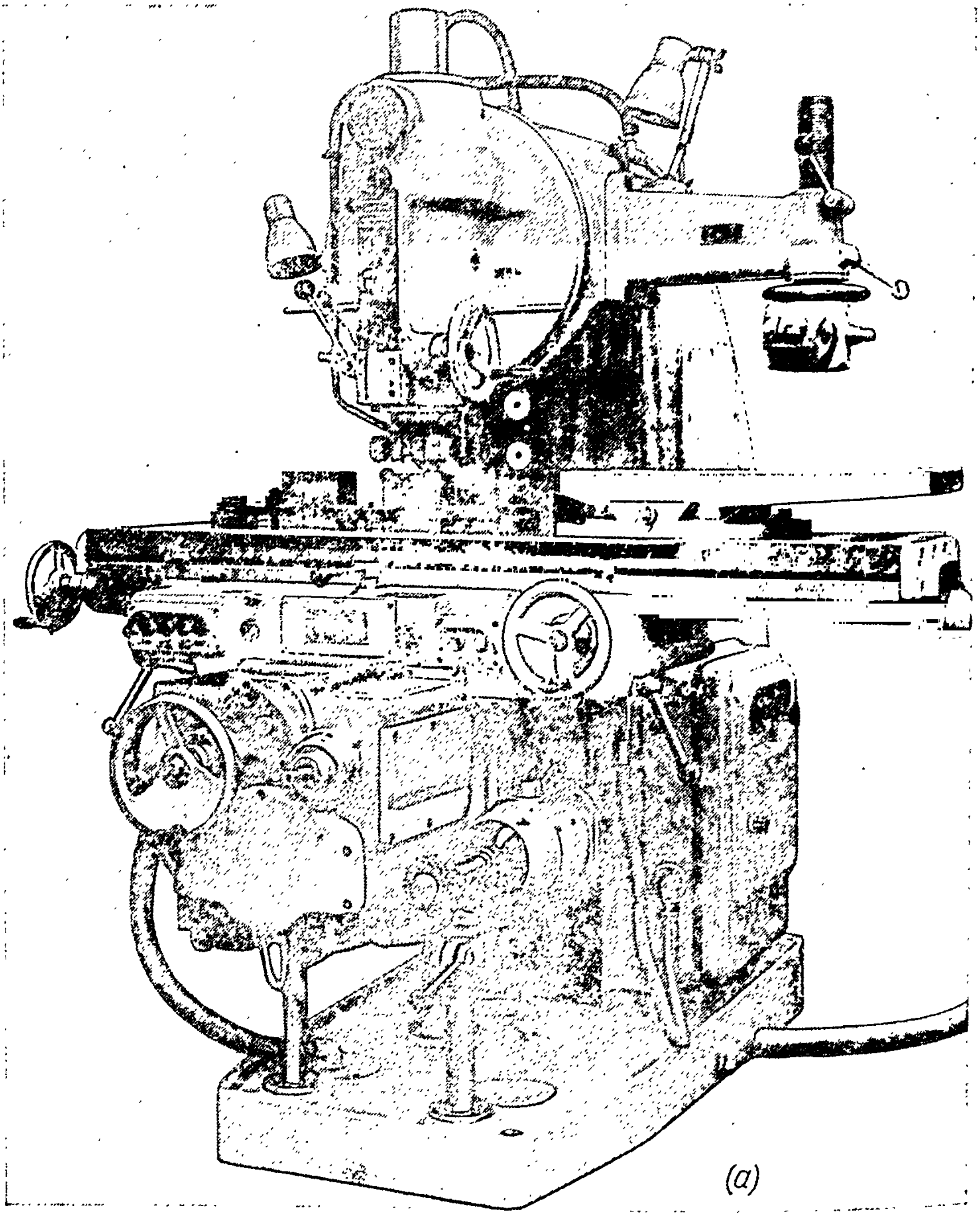
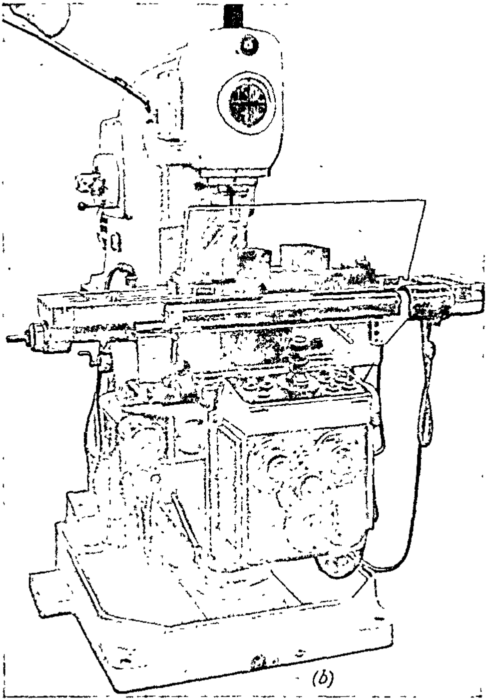


Fig. 164. Vertical tracer-controlled milling machine, model 6M13K (*a*) and



vertical milling machine with a numerical control unit, model 6M11НР (b)

(f) thread-milling machines (see Vol. 2, Part Three, Chapter 5); (g) gear-hobbing machines (see Chapter 13) and (h) numerically-controlled milling machines (see Vol. 4, Part Six).

Tracer-Controlled Duplicating Machines

Parts of complex shape, such as blanking and bending dies, metal foundry patterns, permanent moulds, plastics moulds, propeller blades and turbine blades, are milled in tracer-controlled milling machines. These machines may be modifications of certain standard models or may be designed as special models for machining parts of a single type. They may have one or more (two or three) horizontal or vertical spindles. In the multiple-spindle models, several identical parts or parts that are "mirror images" of each other can be milled simultaneously. The processing capacities of certain tracer-controlled models are extended by the provision of facilities for numerically controlled operation (Fig. 164).

Heavy tracer-controlled milling machines are sometimes equipped with closed-circuit TV units enabling the operator to watch and control the machining process from a convenient position.

The control systems of up-to-date duplicating machines incorporate mechanical, electromechanical and hydraulic servomechanisms in various combinations. Mechanical servomechanisms are used in small machines which do engraving work, or for milling complex surfaces of small parts to templates, in cases when the required machining accuracy is within 0.1 or 0.2 mm.

Figure 165 illustrates a pantograph milling machine for tracing operations. Base *9* mounts column *3* with pivot *4* of pantograph *6*. Spindle *2* of the milling head and tracer spindle *7*, carrying the stylus, rotate in bores of the pantograph. Bracket *5*, joined to pivot *4*, supports the pantograph.

In milling, the operator moves the stylus by hand along the template or model secured on table *8*. At this, the cutter reproduces the motion of the stylus on a reduced scale (from 1 : 1.5 to 1 : 10) and thus mills the blank clamped on table *1* to the required shape. The scale of reduction can be changed by shifting slide blocks *10* and *11* along the arms of the pantograph. Work table *1* and template table *8* can be adjusted in the vertical and horizontal directions. The cutter spindle is driven by a 0.4-kW motor running at 1,480 rpm through two stepped belt transmissions which provide six spindle speeds in the range from 1,750 to 9,600 rpm.

It is necessary to ensure reliable contact between the stylus and the template in millers with mechanical tracing systems. Excess clearances and elastic deformation in the system, and variations in the cutting force and chip cross section in milling may lead to a lack of contact or to vibrations, so that chatter-marks are produced on the work.

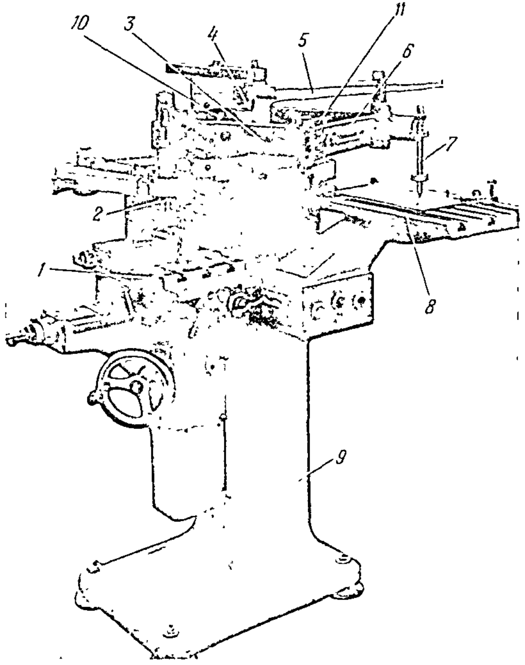
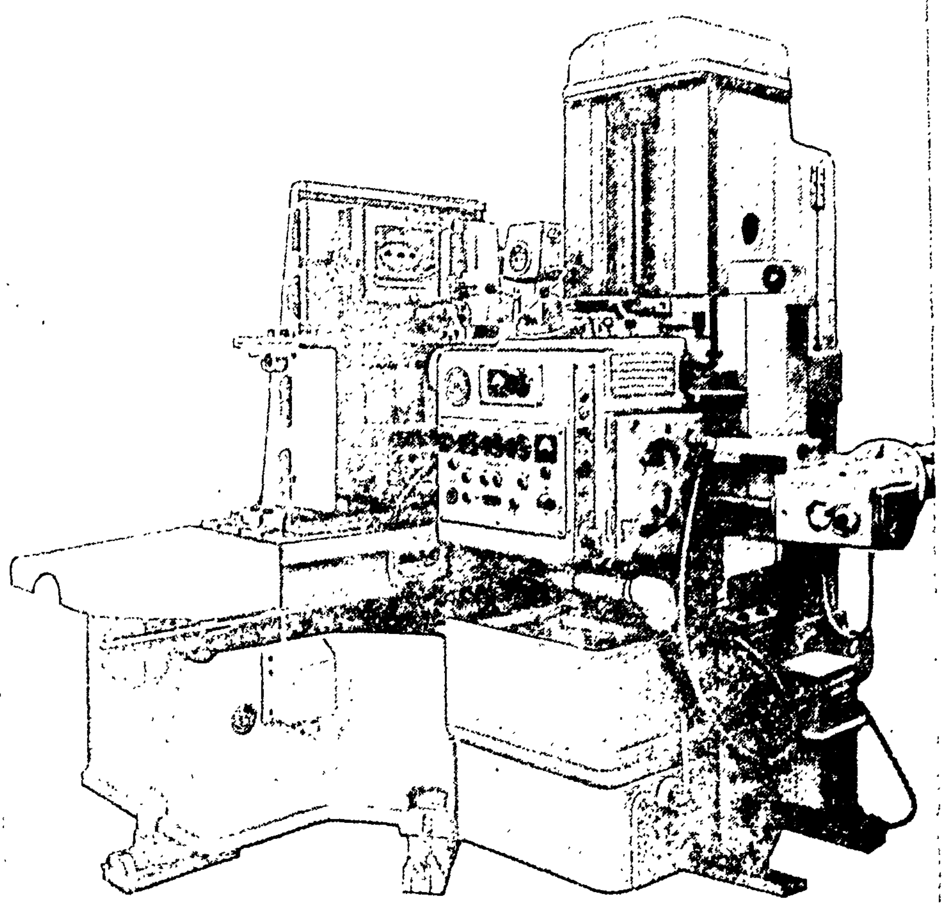


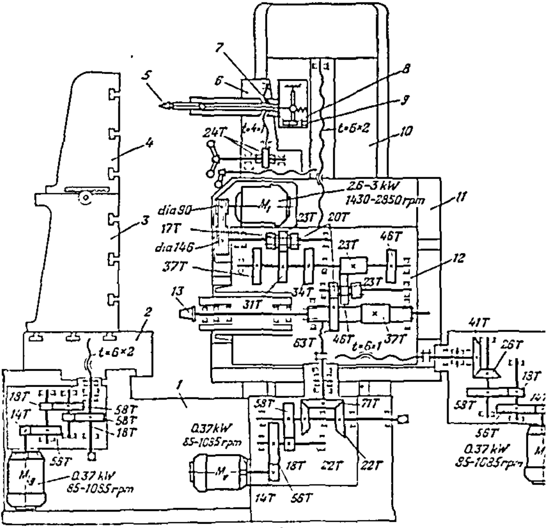
Fig. 165. Pantograph tracer-controlled milling machine, model 6T463



(a)

Fig. 166. Semiautomatic electromechanical tracer-
(a) general view;

In tracer-controlled milling machines with electrical or hydraulic servo-mechanisms, the cutting force has no influence on the force of contact between the stylus and template. This enables the contact pressure on the template to be reduced to 0.1-0.6 kg. Also available are contactless electronic tracing



(b)

controlled milling machine, model 6441Б.
(b) gearing diagram

systems which enable the contour of the work to be milled directly from the drawing or to templates and models made of relatively soft materials.

The semiautomatic electromechanical tracer-controlled milling machine, model 6441Б, and its gearing diagram are shown in Fig. 166. Table 2 trav-

els in the longitudinal direction along the ways of bed *1*. This travel is powered by d-c motor M_{lg} (0.37 kW, 85 to 1,085 rpm) and its speed can be steplessly varied in the following range:

$$v_{lg} = (85 \ldots 1{,}085)\frac{14}{56}\times\frac{18}{58}\times\frac{18}{58}6\times 2 \cong (25 \ldots 315) \text{ mm per min}$$

Uprights *3* and *4* are mounted on the table. The lower upright *3* is for clamping the work, the upper upright *4*, for clamping the model or master.

End mill *13* has 18 different speeds, from 63 to 3,150 rpm, and is driven from a two-speed motor M_1 through a 9-stage speed gearbox mounted in spindle head *12*. This head is mounted on saddle *11* which travels vertically along the ways of column *10*. This motion is powered by a d-c motor M_v and the speed of travel varies as follows:

$$v_v = (85 \ldots 1{,}085)\frac{14}{56}\times\frac{18}{58}\times\frac{22}{71}6\times 2 \cong (25 \ldots 315) \text{ mm per min}$$

Spindle head *12*, to which housing *6* of the tracer unit is secured, can also travel in the horizontal direction along the saddle. This travel is powered by a d-c motor M_{cr} and the speed range is

$$v_{cr} = (85 \ldots 1{,}085)\frac{14}{56}\times\frac{18}{58}\times\frac{26}{41}6\times 1 \cong (25 \ldots 315) \text{ mm per min}$$

During operation of the machine, when table *2* travels in the longitudinal direction, stylus *5*, also called the explorator or form tracer, held against the model by a spring, moves axially, or crosswise, in accordance with the contour of the model. This motion varies the air gap between armature *8* and coil cores *7* and *9*. This alters the inductive currents in these coils and the signals produced are used, after thousandfold amplification and rectification, to supply motor M_{cr} which powers the reproducing motion of the cutter spindle in accordance with the tracing motion of stylus *5*.

When the stylus has passed over the full length of the model, spindle head *12*, together with end mill *13* and stylus *5*, is traversed vertically by an amount equal to the width of the removed layer of metal and then the table automatically reverses. These movements are repeated until the stylus has passed over the whole model.

One of the simplest hydraulic circuits for the servomechanism of a tracer-controlled milling machine is shown in Fig. 167. Its principle of operation consists in the following. During longitudinal travel of table *1* on which blank *2* and template *4* are clamped, stylus *3* of the hydraulic tracing device moves up and down in accordance with the profile of the template.

As the stylus moves downward under the action of spring *6*, slits *b* and *d* of tracer valve *5* are opened. As a result, oil delivered by pump *P* is admitted through slit *b* of the valve to the head and of the hydraulic actuating cylin-

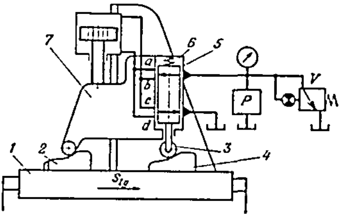


Fig. 167 Hydraulic servomechanism circuit for a tracer-controlled milling machine

der. The pressure of oil in this end of the cylinder forces the piston together with its rod, spindle head 7 and the body of tracer valve 5 downward, while oil from the rod end of the cylinder drains through slit *d* back to the tank. The spindle head will continue to travel downward until slits *b* and *d* are closed by the body of the tracer valve. Relief valve *V* protects the pump against overloads.

When the stylus moves upward, slits *a* and *c* of the tracer valve are opened and oil from pump *P* is admitted through slit *a* to the rod end of the actuating cylinder, while from the head end the oil drains through slit *c* back to the tank. At this, the piston together with the spindle head and body of the tracer valve travels upward until slits *a* and *c* are again closed by the valve body.

Thus the power cylinder, rigidly linked to the spindle head, reproduces the motions of the tracer valve stylus. The tracing accuracy may be very high, of the order of 0.01 or 0.02 mm.

Keyway Milling Machines

Keyway milling machines are intended for milling keyways in shafts of various sizes. In certain models the size of the keyway depends only upon the size of the cutter (end mill)

Such machines usually operate on one of the following cycles: (1) feed-down to the full depth of the keyway followed by longitudinal feed along the length of the keyway (Fig 168*a*), and (2) operation on a reciprocal milling cycle, i.e., repeated rapid reciprocating longitudinal travel of the cutter along the length of the keyway with feed-down at the end of each stroke

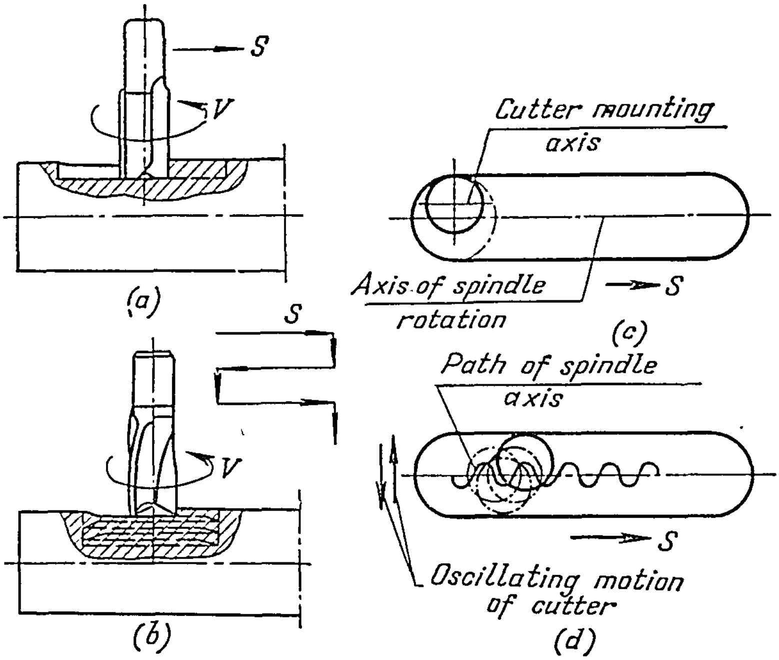


Fig. 168. Methods of milling keyways

equal to a small part of the full depth (Fig. 168*b*). The output is higher with the first method. The second method provides a substantially longer tool life. This is an important feature for machines of this type since after the cutter is sharpened, its diameter will be reduced and it can no longer mill keyways of accurate width.

Keyway milling machines that operate on another principle can produce keyways of accurate width independently of the actual diameter of the end mill. Such machines operate according to the first of the methods described but the end mill is either mounted eccentrically in relation to the spindle axis (Fig. 168*c*), or it has an additional oscillating motion in the transverse direction (Fig. 168*d*).

Depending upon the arrangement of the spindles and their number, keyway milling machines are classified as horizontal or vertical, and single- or multiple-spindle models.

Figure 169 illustrates a vertical keyway milling machine, model 692M, operating with an end mill on a reciprocal milling cycle. The machine has spindle head *1*, base *4*, knee *3* which can be adjusted vertically in setting up, and table *2* which can be traversed crosswise by hand.

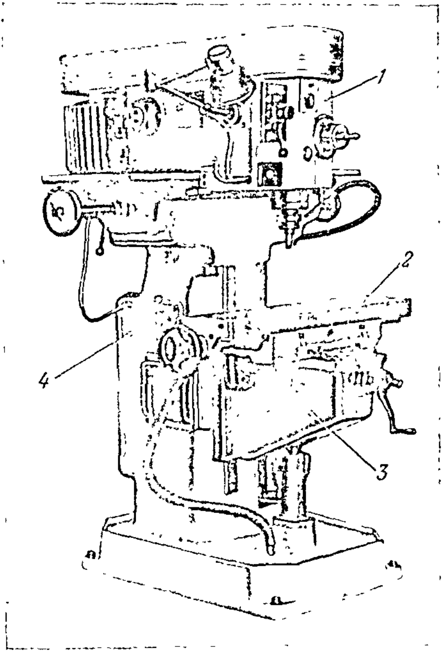


Fig. 169. Vertical keyway milling machine, model 692M

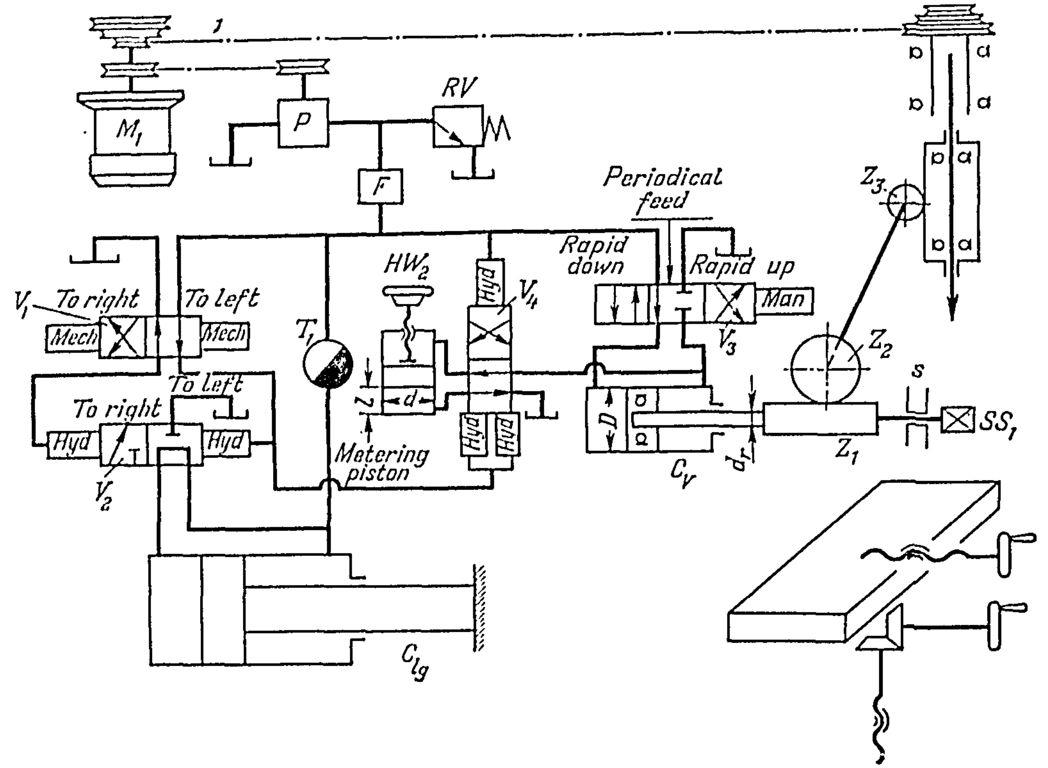


Fig. 170. Combined hydraulic circuit and gearing diagram of the model ДФ-82Д keyway milling machine

Shown in Fig. 170 is the hydraulic circuit and gearing diagram of the model ДФ-82Д keyway milling machine.

This machine can be used for milling keyways from 3 to 20 mm wide and up to 300 mm long. At the end of each longitudinal stroke the cutter is fed down not more than 0.6 mm. The rate of longitudinal feed ranges from 450 to 1,200 mm per min.

The spindle head has a hydraulic drive providing the longitudinal feed and the vertical feed of the spindle into the work. The spindle has twelve speeds ranging from 270 to 3,380 rpm. It is driven by a two-speed motor M_1 through a three-step V-belt transmission with change pulleys (Fig. 170). The same motor drives pump P of the hydraulic circuit. Oil is delivered from pump P through filter F to pilot valve V_1 which operates valve V_2. Pilot valve V_1 is shifted at the end of each longitudinal stroke by adjustable trip dogs. At the same time, oil from pump P is delivered through flow-control valve T_1 to the rod end of hydraulic cylinder C_{lg} which provides the longitudinal feed. Depending upon the position of valve V_2, hydraulic cylinder

C_{lg} travels either to the right or left. Upon travel to the right, the head end of the cylinder is connected through valve V_2 with the tank; upon travel to the left, the rod and head ends of the cylinder are connected together. In the latter case, cylinder C_{lg} operates on a differential circuit (see Part Four). The rate of longitudinal feed is varied steplessly by flow-control valve T_1 in the range from 450 to 1,200 mm per min.

Vertical travel of the spindle quill can be accomplished either by hand from square shank SS_1 whose rotation is transmitted through the worm gearing $\frac{z_1}{z_2}$ to rack pinion z_3 which meshes with the rack cut on the quill, or by power from hydraulic cylinder C_v whose piston moves worm z_1 axially and thus rotates worm wheel z_2.

Periodical vertical feed at the end of each longitudinal stroke of the spindle head is transmitted to the cutter due to metered release of oil from the rod end of hydraulic cylinder C_v. In the middle position of valve V_3, oil is delivered from pump P through filter F and valve V_3 to the head end of cylinder C_v. From the rod end, oil is forced out through valve V_4 to the metering cylinder which has a floating piston whose stroke can be regulated by handwheel HW_2. One of the ends of this cylinder is connected through valve V_4 to the tank while the other is connected to the rod end of cylinder C_v. At the moment of table reversal, pilot valve V_1 operates, not only valve V_2, but also valve V_4, which connects the empty end of the metering cylinder to the rod end of cylinder C_v and the full end to the tank. As a result, the following volume of oil is drained to the tank:

$$V = \frac{\pi d^2}{4} l$$

where d = diameter of the metering cylinder
l = set-up stroke of the metering piston.

This allows the piston of hydraulic cylinder C_v to move an amount equal to

$$l_1 = \frac{4V}{\pi(D^2 - d_r^2)} = \frac{d^2}{D^2 - d_r^2} l$$

where D and d_r are the diameters of hydraulic cylinder C_v and its rod, respectively.

This will feed the spindle quill down by the amount S_v, equal to

$$S_v = \frac{ld^2 m_3 z_3}{(D^2 - d_r^2) m_2 z_2}$$

where m_2 and m_3 = modules of the worm wheel and rack pinion, respectively
z_2 and z_3 = number of teeth on the worm wheel and rack pinion, respectively

The down feed S_v can be varied, by turning handwheel HW_2, in the range from 0.05 to 0.6 mm per stroke.

The periodical feed ceases when the end of worm z_1 reaches stop S.

When valve V_3 is shifted to the RAPID UP position, the piston of hydraulic cylinder C_v returns to its initial position. The spindle quill can be rapidly lowered within the limits established by the value S_v by shifting valve V_3 to the RAPID DOWN position.

Circular Sawing Machines

Circular sawing machines are intended for cutting off rolled stock of various shapes. These machines use circular saws from 350 to 2,000 mm in diameter and from 4 to 12 mm thick (Fig. 171). Saw rotation (the primary cutting motion) is powered from an electric motor through a mechanical speed gearbox. The vertical or horizontal feed motion is obtained from a hydraulic drive which is also used to clamp the stock being cut. A hydraulic drive enables a semiautomatic or automatic cycle to be more simply obtained and facilitates setting-up operations.

The combined hydraulic system and gearing diagram of the automatic and semiautomatic circular sawing machines, models 8A631A and 8A631, respectively, is shown in Fig. 172. The 350-mm saw has six speeds. It is powered by a 2.8-kW motor M_1 through the double and triple cluster gears of the speed gearbox. The hydraulic drive, assembled of standard items, provides for rapid approach, working feed and rapid return of the spindle head, as well as clamping and unclamping of the stock. In the automatic model (8A631A), the stock is also gripped and fed hydraulically.

When the machine is started, motors M_1 and M_2 are switched on simultaneously and solenoid Sd_2 of valve V_2 is energized. Oil is delivered by pump P through filter F and valve V_2 in its right-hand position to the upper end of vertical clamping cylinder C_{vc}. After the stock is released and after the oil pressure is built up to 25 kg per sq cm, the oil bypasses valve V_7 and passes through flow-control valve T_2 to drive hydraulic motor HM of the chip disposal mechanism. If the oil pressure before flow-control valve T_2 exceeds 12 kg per sq cm, the surplus oil will drain through valve V_8 to the tank.

Upon transmission of the command STOCK GRIP, solenoids Sd_3 and Sd_4 of valves V_3 and V_4 are energized. Oil passes through valve V_3 in its left-hand position to stock gripping cylinders C_{sg} whose pistons compress their springs and grip the bar of stock. After the bar is gripped and the pressure is built up to 12 kg per sq cm, valve V_9 is opened. This valve connects the head end of bar feed cylinder C_{bf}, through valve V_4 in its right-hand position, with pump P. This feeds out the bar of stock. From the rod end of cylinder C_{bf} the oil drains back to the tank through valve V_4 in its right-hand position.

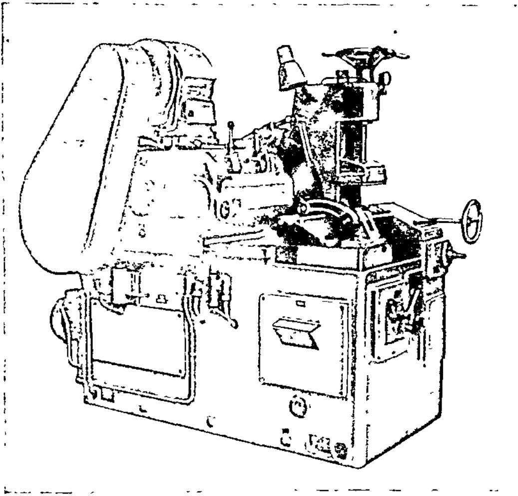
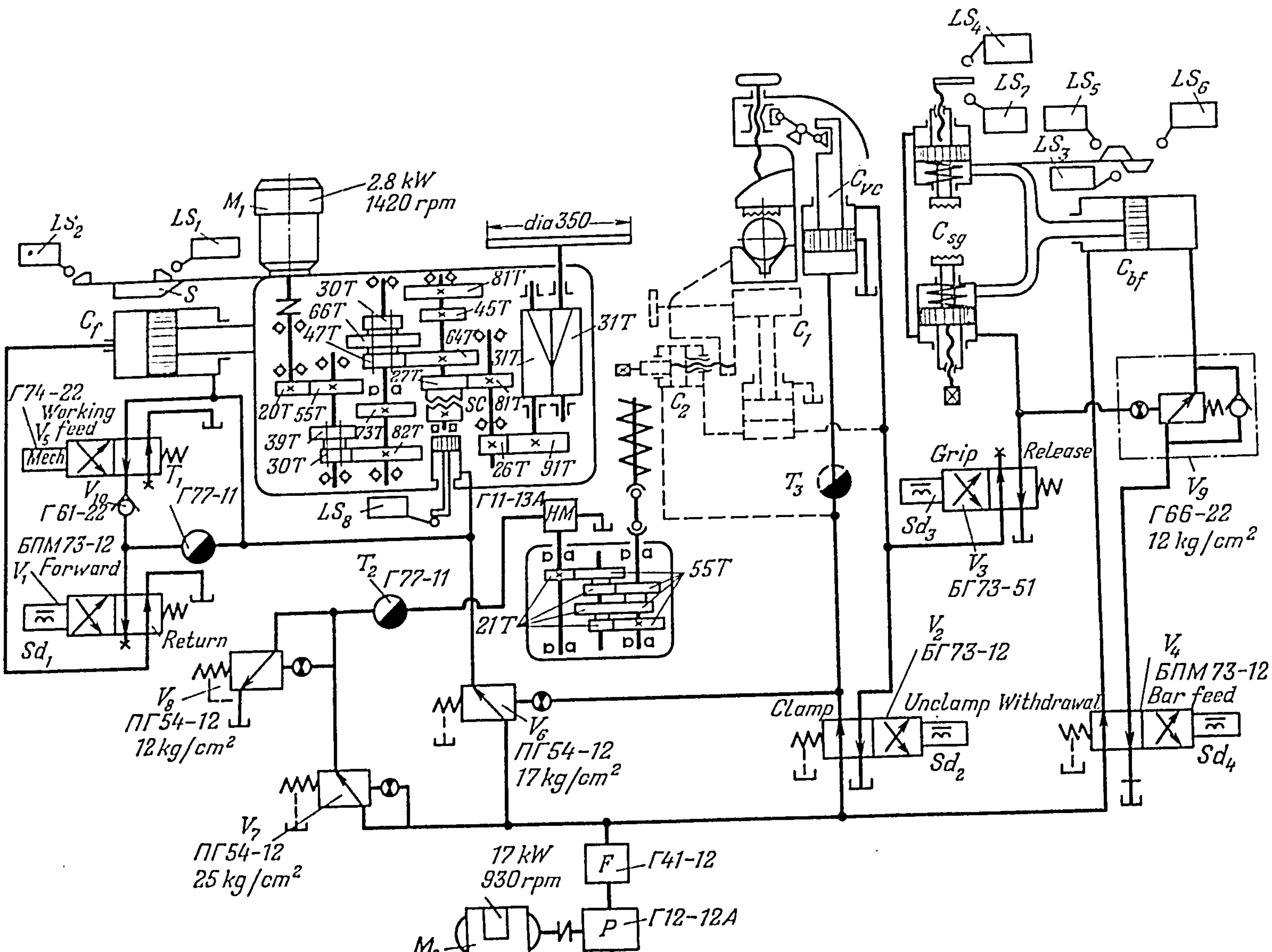


Fig. 171. Circular sawing machine, model 8641

At the end of the bar feed, limit switch LS_3 de-energizes solenoid Sd_3. Under spring action, the pistons of cylinders C_{fg} are spread apart, forcing the oil through valve V_3 in its right-hand position back to the tank. At the end of the retraction of the grips, limit switch LS_4 de-energizes the solenoids Sd_4 and Sd_2 of valves V_4 and V_2, and simultaneously energizes solenoid Sd_1 of valve V_1. When solenoid Sd_4 is de-energized and the spool of valve V_4 returns to its left-hand position, the carriage is withdrawn.



LS4
LS7
LS5
LS6
LS3
LS'2
LS1
S
M1
2.8 kW
1420 rpm
dia 350
Cvc
Csg
Cbf
Cf
C1
C2
30T
66T
47T
81T
45T
64T
31T
27T
SC
81T
20T
55T
73T
82T
39T
30T
26T
91T
Г74-22
Working feed
V5
Mech
T1
Г77-11
V10
Г61-22
БПМ73-12
V1
Forward
Return
Sd1
LS8
Г11-13А
HM
55T
21T
T2
Г77-11
T3
Grip
Release
Sd3
V3
БГ73-51
V9
Г66-22
12 kg/cm²
V8
ПГ54-12
12 kg/cm²
V6
ПГ54-12
17 kg/cm²
V2
БГ73-12
Clamp
Unclamp
Withdrawal
Sd2
V4
БПМ73-12
Bar feed
Sd4
V7
ПГ54-12
25 kg/cm²
17 kW
930 rpm
F
Г41-12
P
Г12-12А

When solenoid Sd_2 is de-energized, the spool of valve V_2 shifts to the CLAMP position and the stock is clamped. When the oil pressure has been built up to 17 kg per sq cm, valve V_6 opens, admitting oil into the cylinder of hydraulic safety clutch SC and into the rod end of the spindle head feed cylinder C_f and, simultaneously, through the rapid approach position of valve V_5, nonreturn valve V_{10} and valve V_1 in its left-hand position to the head end of cylinder C_f. Thus this cylinder operates on a differential circuit (see Part Four) and the spindle head rapidly approaches the stock. At the end of the rapid approach, stop S shifts the spool of valve V_5 to its left-hand position. The flow of oil from the rod end to the head end of cylinder C_f depends upon the set-up area of the orifice in flow-control valve T_1 which determines the rate of working feed. During working feed, surplus oil drains through valve V_7.

At the end of the working feed, limit switch LS_1 de-energizes solenoid Sd_1. As a result, the head end of cylinder C_f is connected to the tank and the spindle head is rapidly withdrawn. At the end of this movement, when the spindle head returns to its initial position, limit switch LS_2 energizes solenoids Sd_2, Sd_3 and Sd_4 whose circuits have been prepared by limit switch LS_6. At this, the stock is unclamped and gripped by the bar feed device. As soon as the oil pressure builds up above 12 kg per sq cm, the bar of stock is fed out again. Limit switch LS_7 switches off the machine when the whole bar of stock has been cut up, while limit switch LS_8 stops the machine if the load on the saw blade exceeds the permissible value.

The semiautomatic model (8A631) does not have either a bar feed mechanism or valves V_3 and V_4. Instead, this model has a stock lifting cylinder C_1, side clamping cylinder C_2 and a flow-control valve T_3 which controls the sequence of operation of the side and vertical clamping facilities. Cylinders C_1 and C_2 and valve T_3 are shown with dashed lines in the diagram.

Drum-Type Milling Machines

This type of milling machine is intended for simultaneously machining two parallel end surfaces of housing-type parts or the end faces of shafts. The work is clamped to the faces or in the V-blocks of a slowly rotating drum *4* (Fig. 173) from 500 to 2,000 mm in diameter, and passes between two or three series of cutters; one pair of opposed cutters serves for finish milling. The workpieces are loaded and unloaded, without stopping the machine, by an automatic loading device, or by hand using a special fixture. Spindles *3* are powered through mechanical gearboxes from motors arranged either on each spindle head or on each housing. In the second case, one motor drives the group of spindles mounted on the housing. The drum is driven by a separate motor *1* through worm gearing arranged in guard *2*.

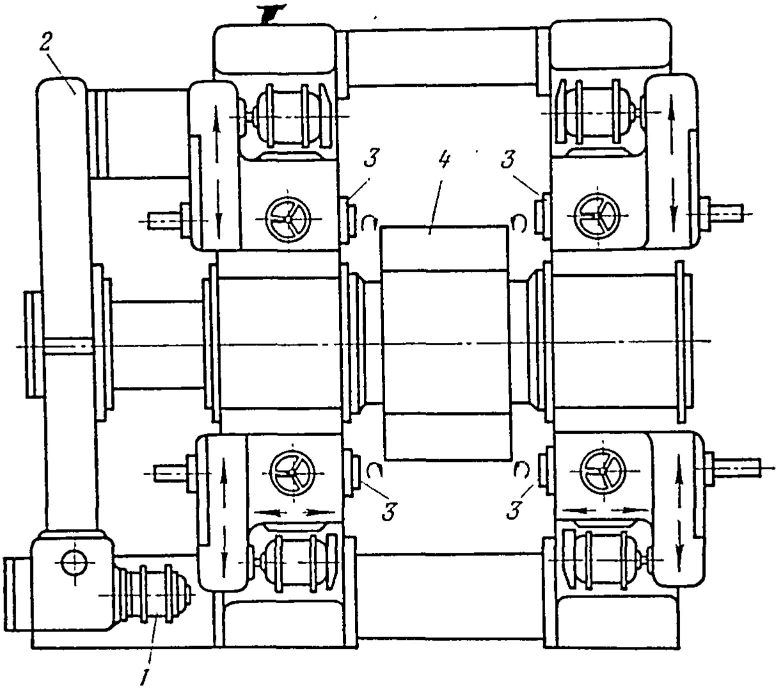


Fig. 173. Drum-type milling machine

Circular Milling Machines

Circular milling machines serve for machining surfaces of revolution with plain or form milling cutters having teeth on the sides of the cutter, as well as face mills and hollow mills.

The blanks for short contoured parts are milled by one or two form cutters whose profile corresponds to that required on the work. In addition to the primary cutting motion, cutter rotation, two feed motions are used: feed-in and circular feed s_c. The feed-in motion may be tangential s_t or radial s_r and is accomplished with the blank stationary or rotating slowly (Fig. 174*a*). To completely mill the blank after the cutter has been fed to the required depth, it is sufficient to rotate the work through 185° if two cutters are used, or through 365° for a single cutter.

In milling cylindrical surfaces of considerable length with plain milling cutters (Fig. 174*b*), longitudinal feed s_{lg} along the elements of the surface of revolution is transmitted to the cutters when, after infeed s_r, they reach the required depth of cut and after the blank has turned through an angle of 185° (or 365° for a single cutter).

In addition to their high output, advantages of circular milling machines are the long cutter life, due to the relatively short time each tooth of the cutter is actually engaged in cutting metal, and the easily handled chips produced, requiring no chip breakers or other devices.

8-5. Holding the Tool and the Work in Milling Machines

The nose of milling machine spindles has been standardized (USSR Std GOST 836-62). It has a locating flange (outside diameter) and a steep taper socket with 7 : 24 taper ($3^1/_2$ in. per ft) for better location of arbor and end mill shanks. Rotation is transmitted to the cutter through driving keys secured to the end face of the spindle.

Large face milling cutters are mounted directly on the spindle flange and are secured to the end face by screws. Rotation is transmitted to the cutters through the driving keys of the spindle (Fig. 175).

Plain and side milling cutters are mounted on an arbor whose taper shank is drawn up tight into the taper socket of the spindle with a draw-in bolt. Milling arbors may be long (Fig. 176) or short (stub arbors). The outer end of a long arbor is supported by an overarm support in the knee-type machines with a horizontal spindle, or by the opposing spindle in the duplex fixed-bed models. The cutter is mounted at the required position on the arbor on a key or without one and is clamped between collars or spacers with a large nut.

On stub arbors *1*, the end mills or face milling cutters are driven either by an axial (Fig. 177*a*) or an end (Fig. 177*b*) key *2*.

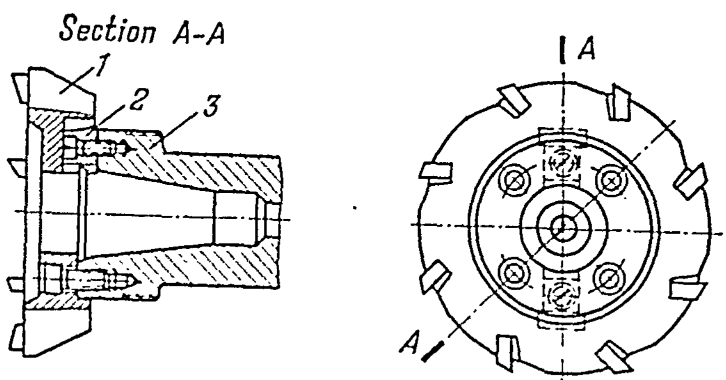


Fig. 175. Holding a face milling cutter on the spindle of a milling machine:
1—cutter; *2*—driving key; *3*—spindle

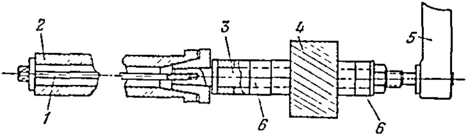


Fig. 176. Holding an arbor-type cutter on a long arbor:
1—draw-in bolt, 2—spindle, 3—arbor; 4—cutter, 5—arbor support; 6—collars or spacers

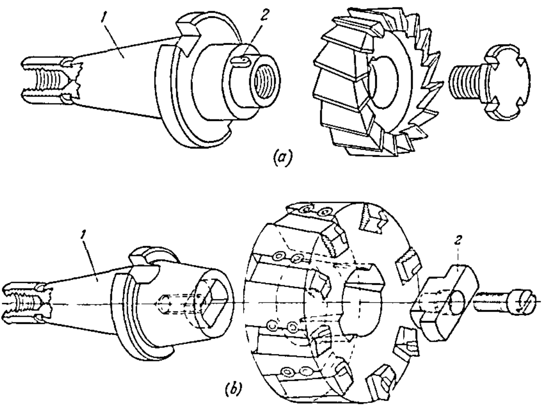


Fig. 177. Holding shell end mills and face milling cutters on stub arbors

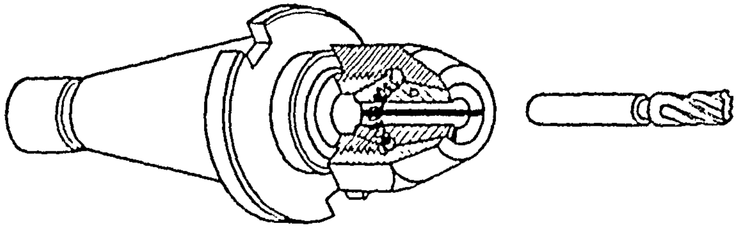


Fig. 178. Chuck for holding straight-shank end mills

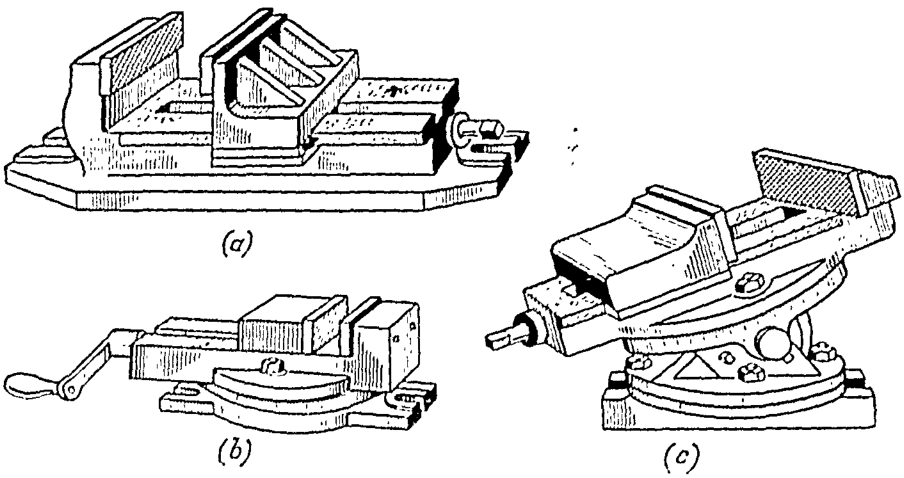


Fig. 179. Vises:
(a) plain; (b) swivel; (c) universal

End mills, T-slot milling cutters and others of the taper shank type are secured with a draw-in bolt either directly in the taper socket of the spindle or by means of adapters. Straight-shank cutters are held in chucks (Fig. 178).

Small blanks are most frequently clamped in general-purpose milling machines in a plain, swivel or universal vise (Fig. 179) fastened to the work table. In contrast to those of a plain vise, the jaws of a swivel vise can be turned about a vertical axis to the required angle and clamped. A universal vise can be additionally swivelled about a horizontal axis through an angle up to 90°. Shaped jaws are sometimes used instead of the flat type to clamp parts of irregular shape. Blanks too large for a vise are clamped directly on the work table, using standard fastening elements such as strap clamps, support blocks, chisel points, step blocks, T-slot bolts, etc. (see Fig. 203).

CHAPTER 9

PLANERS, SHAPERS AND SLOTTERS

The distinguishing feature of planing, shaping and slotting is that the shape-generating motion consists of a straight-line reciprocating motion at the cutting speed and a straight-line intermittent feed motion.

In planers, the work reciprocates with the cutting speed; in shapers and slotters, this motion is imparted to the cutting tool.

All machines of this group are intended chiefly for machining horizontal, vertical and inclined flat surfaces, or combinations of such surfaces, on workpieces of cast iron, steel, nonferrous metals and certain types of plastics.

Planers, shapers and slotters differ in the arrangement of the principal parts and in the kind of work they do.

The attainable and economically feasible accuracy and surface finish obtained on these machines are listed in Table 24.

TABLE 24

Planing, shaping and slotting	Grade of accuracy		Surface finish class
	Limits	Mean economically feasible	
Roughing	4-7	5	3-4
Finishing	3a-4	4	4-5
Precision	2a-3a	3	6-8

9-1. Planers

Planers are used to produce flat surfaces on work which is impossible or inconvenient to machine in a miller. Planers find application in medium and heavy engineering plants for piece and small-lot production, as well as in repair shops. Rough (surface finish $\nabla 3$-$\nabla 4$) and finish ($\nabla 4$-$\nabla 5$) planing can be performed, as well as precision planing with a high accuracy and a fine surface finish ($\nabla 6$-$\nabla 8$).

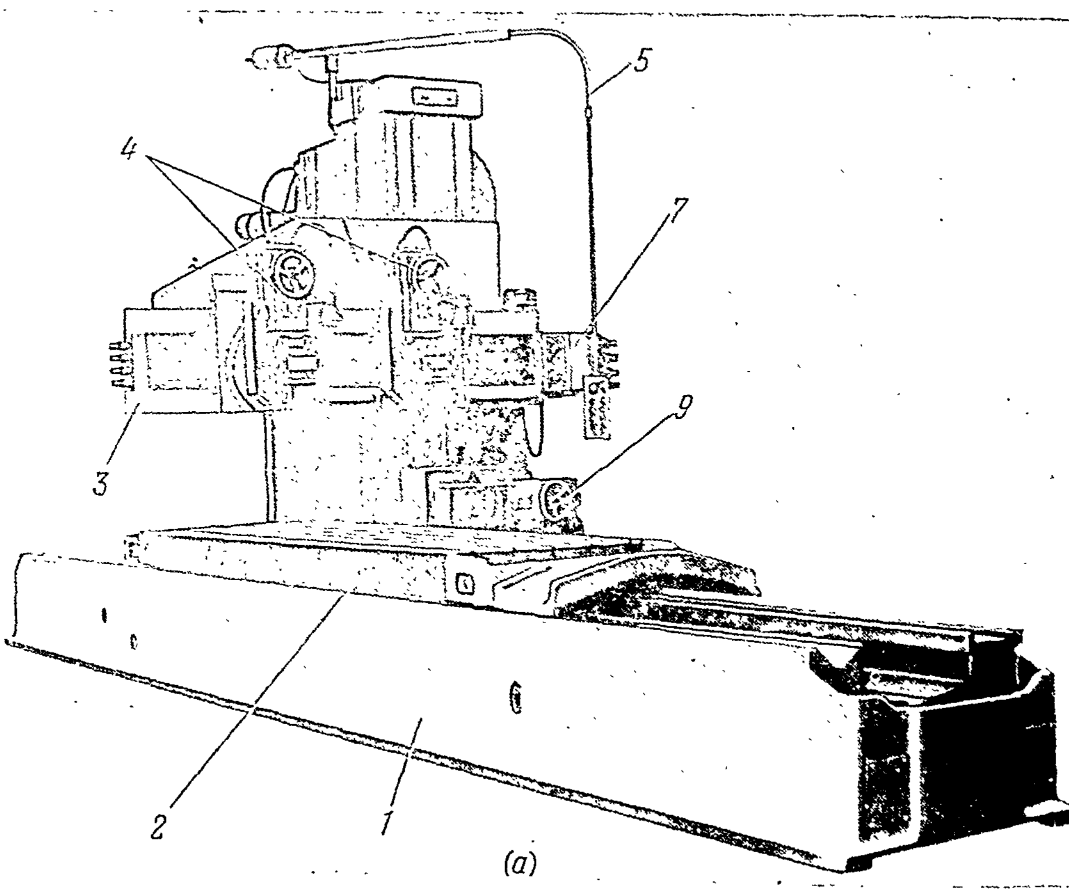
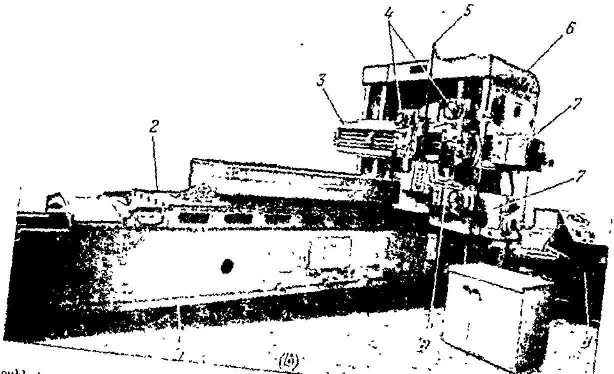


Fig. 180. Openside planer, model 7112 (a) and
1—bed; 2—table; 3—crossrail; 4—crossrail (vertical) tool heads; 5—pendent control station; 6—hou

The work is clamped on the reciprocating table and travels past the stationary tool head. Chips are cut by the stationary single-point tool or tools only during the forward stroke of the table. The tool feed usually occurs during table reversal from the return stroke to the cutting (forward) stroke, i.e., just before the beginning of the cutting stroke.

The very accurate surfaces that may be produced by planing are easier to scrape than milled surfaces.

Items specifying the capacity of a planer are the maximum length of the work that can be planed (maximum table stroke), maximum width planed and the maximum height to which the crossrail with the tool heads can be elevated. These are sometimes referred to as the length, width and height of the planer and determine the size of the work that can be planed.



double-housing planer, model 7210 (b).
sings and arch; 7—feed gearboxes of the crossrail and side tool heads, 8—table drive, 9—side tool head

The maximum length planed by up-to-date general-purpose planers ranges from 2 to 12.5 m, the width from 0.6 to 5 m, and the height to the crossrail from 0.7 to 4.5 m (Table 25).

Depending upon the construction of the crossrail, planers are classified as double-housing, in which the crossrail is supported by two housings, and openside, in which it is supported by one housing. Openside planers (Fig. 180a) are used to machine [illegible] to be machi[illegible] e size of the surfaces size ca[illegible] : in which the overall housing [illegible]. Such work may include long and wide parts that overhang the table from one side, but do not require machining over their full width. Openside planers can be employed for performing all standard planing operations.

TABLE 23

Type	Model	Maximum size of work planed, width × length × height, m	Maximum permissible weight of work, tons	Number of tool heads		Table cutting stroke speed, m/min	Feed per full stroke of table, mm		Power of main drive motor, kW	Net weight, kg approx.	Remarks
				crossrail	side		horizontal	vertical			
Open-side planers	7106	0.63×1.6×0.55	2	—	1	4 to 60	0.5 to 25	0.75 to 12.5	13	17,000	
	7108	0.8×2.5×0.7	3	2	1	4 to 60 / 6 to 90	0.5 to 25	0.75 to 12.5	40	24,000	
	7110	1×3×0.9	4.5	2	1	4 to 60 / 6 to 90	0.5 to 25	0.75 to 12.5	40	30,000	
	7112	1.25×4×1.12	8	2	1	4 to 48 / 6.5 to 80	0.5 to 25	0.75 to 12.5	55	31,500	
	7116	1.6×6.3×1.25	12	2	1	4 to 48 / 6.5 to 80	0.5 to 25	0.75 to 12.5	55	42,000	
	7208	0.8×2.5×0.7	3	2	1	4 to 60 / 6 to 90	0.5 to 25	0.25 to 12.5	40	22,000	
	7210	1×3×0.9	4.5	2	1	4 to 60 / 6 to 90	0.5 to 25	0.25 to 12.5	40	27,000	
	7212	1.25×4×1.12	8	2	1	4 to 48 / 6.5 to 80	0.5 to 25	0.25 to 12.5	55	31,500	
	7216	1.6×6.3×1.25	12	2	1	4 to 48 / 6.5 to 80	0.5 to 25	0.25 to 12.5	75	48,000	
	7220	2×5×1.8	20	2	2	1.5 to 75	0.5 to 50	0.25 to 25	125	75,000	Furnished with milling (25-1,250 rpm, 20 kW) and grinding (1,460 rpm, 14kW) heads

Double-housing planers	7225	2.5×6.3×2.5	45	2	2	1.2 to 60	0.5 to 50	0.25 to 25	125	83,000	Furnished with milling (25-1,250 rpm, 20 kW) and grinding (1,460 rpm,14 kW)heads
	7232	3.2×8×3	65	2	2	1.2 to 60	0.5 to 100	0.25 to 50	100×2	122,000	Furnished with milling (20-1,000 rpm, 28 kW) and grinding (975 rpm,28 kW)heads
	7240	4×10×3.8	100	2	2	1 to 50	0.5 to 100	0.25 to 50	100×2	343,000	Furnished with milling (2-50; 10-500 rpm, 28 kW) and grinding (975 rpm,28 kW)heads
	7250	5×12.5×4.5	200	2	2	1 to 50	0.5 to 100	0.25 to 50	125×2	392,000	Furnished with milling (10-500 rpm, 28 kW) and grinding (975 rpm,28 kW)heads
Plate planers	7806	1.5×6×0.2				4 to 50	0.25 to 6.2	10.5 to 12.5	28	26,000	Travelling tool carriage; stationary table
	7806B	1.5×12×0.2				4 to 40	0.25 to 6.2	10.5 to 12.5	28	37,000	Ditto

The model 7210 double-housing planer is shown in Fig. 180*b*; the gearing diagram of the model 7212 planer is shown in Fig. 181.

The bed of this planer is a box-shape grey-iron casting with two longitudinal ways, one flat and the other of the V type. Heavy planers, for example, model 7240, have three ways. Long planers may have a bed consisting of several castings, carefully machined and bolted together.

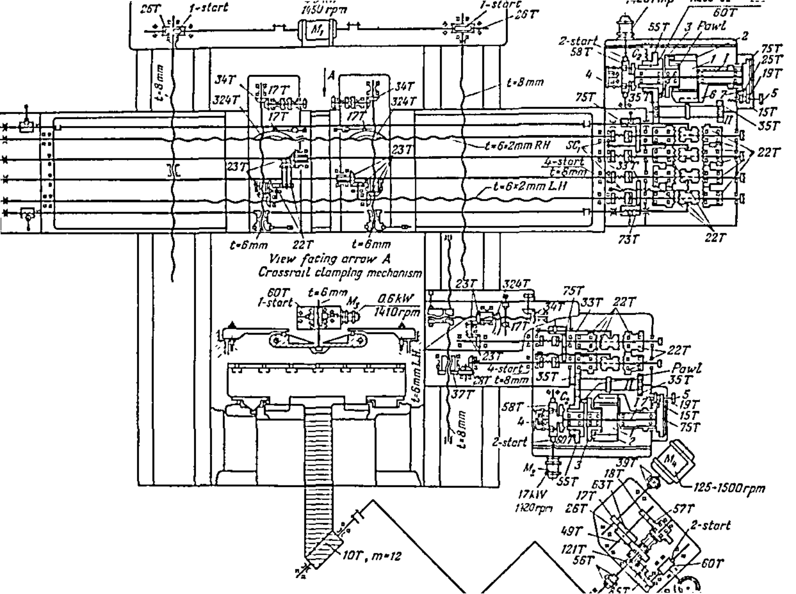
The bed ways are protected against dust and chip particles by steel bands secured to the ends of the ways and passing through a slot in the table. A box-shape table with internal stiffening ribs travels back and forth along the bed ways. The ways are faced with plastic strips to increase the wear resistance and to prevent scoring. T-slots run the whole length of the working surface of the table and receive T-bolts for clamping the work. Rows of holes between the T-slots are provided to accept stop pins preventing movement of the work under heavy cuts.

The helical rack of the table drive is mounted underneath the table between the ways. Spur or worm racks are sometimes used in place of the helical rack. A worm rack, meshing with a worm, provides smoother action, both in travel and during reversals, because more threads of the worm mesh simultaneously with the rack than do the teeth of a pinion with a spur or helical rack.

The table (see Fig. 181) of the model 7212 planer is driven by a d-c motor through a mechanical speed gearbox. This enables infinitely variable cutting and return stroke speeds to be obtained independently of each other. The following automatic cycle of table reciprocation is available: slow speed as the tool is started in the cut, acceleration to the preset cutting speed, a cutting stroke at this speed, slowing down as the tool leaves the cut, rapid table return at the preset return stroke speed, and feed of the tool heads. The cycle is controlled by a mechanism mounted on the speed gearbox. It slows down the table speed at the required points by an amount depending upon the preset feed. This provides for a constant overrun of the table at the ends of the stroke, and for minimum overtravel.

The model 7212 planer has a special braking device which prevents the table from running off the bed due to a mechanical or electrical failure of any kind. This device consists of three-tooth broaches mounted at the two ends of the table. If the table rack runs out of mesh with its pinion, the corresponding broach will cut into a steel strip fixed to the bed, thus bringing the table gradually to a stop.

The frame of the planer consists of two housings secured below to machined surfaces of the bed and connected on top by a cross-member called the arch. The side tool heads and the crossrail travel vertically along the ways of the housings. The weight for counterbalancing the side tool head is arranged inside the housing. The crossrail elevating mechanism is mounted in the housings and the arch.



1450 rpm
1-start
26T
t=8 mm
34T
324T
17T
23T
22T
t=6mm
A
t=6×2mm RH
t=6×2mm LH
4-start
t=8mm
SC1
33T
73T
75T
2-start
58T
55T
60T
3 Pawl
2
25T
19T
5
15T
35T
View facing arrow A
Crossrail clamping mechanism
60T
1-start
t=6mm
M3
0.6kW
1410rpm
t=6mm L.H.
37T
Pawl
M2
17kW
1120rpm
M4
125-1500rpm
39T
18T
63T
17T
26T
57T
49T
121T
56T
10T, m=12

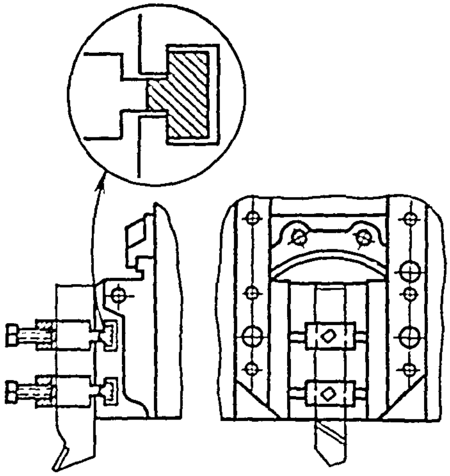


Fig. 182. Clamping single-point tools on the tool block of the tool head on a planer

The crossrail is a cast-iron beam of box section, considerably stiffened by a central web and ribbing. It carries the two crossrail (vertical) tool heads, tool head feed gearbox, duplicate controls and the crossrail clamping mechanism.

The crossrail is clamped on the housings by means of a lever system (see Fig. 181). The crossrail is traversed by motor M_1 through worm reducing gears $\left(i = \frac{1}{26}\right)$ linked to two vertical screws with a pitch $t = 8$ mm, located in the housings. Crossrail traverse is interlocked with its clamping on the housings. When the push button CROSSRAIL UP or CROSSRAIL DOWN is pressed, the crossrail begins travelling in the required direction after the clamps are released. The crossrail is automatically reclamped at the end of its traverse motion.

All the tool heads are identical in construction. The harp with the slide can be swivelled by means of a worm to an angle up to $\pm 60°$ for planing inclined surfaces. Either solid or gang tools are clamped on the tool block (Fig. 182) of the tool head. During the return stroke of the table the tool with the tool block is automatically lifted from the machined surface. Before the beginning of the cutting stroke the tool block is returned to its position in the clapper box by the application of a certain force that eliminates any clearance.

The feed gearbox provides the tool head drive and enables the rate of feed to be selected. The gearbox can be controlled from either end of the crossrail. The tool heads have positioning traverse from inching push buttons and intermittent feed in both the horizontal and vertical directions.

The feed gearbox is powered by a separate flange-mounted reversible motor M_2 (Fig. 181) from which rotation is transmitted through worm gearing $\frac{2}{58}$ to main shaft I of the feed gearbox. Disk *1*, on which friction clutch *2* is mounted, is keyed on shaft I. The friction clutch is linked through a pin to disk *3* which carries the pawl of a ratchet mechanism. The pawl transmits rotation to ratchet wheel $60T$ and to output gear $55T$, rigidly secured to the ratchet wheel. From gear $55T$, rotation is transmitted further to distributing shaft II and through two gears $35T$ to the combined clutch members and gears $22T$ mounted freely on four shafts of the gearbox and

rotating in different directions. Engagement of the clutch members, sliding on splines along these shafts, with either one or the other of the two combined clutch members and gears on each shaft enables shaft rotation to be reversed. This reverses the feed of one tool head in one direction.

The four shafts are linked to the feed screws and feed rods in the crossrail through safety jaw clutches SC_1.

The upper and lower shafts are linked to feed screws ($t = 6 \times 2$ mm) of the crossrail and provide horizontal feed of the tool heads; the middle shafts are linked to the feed rods which provide vertical feed of the tool head slides.

Intermittent power feed of the tool heads takes place in the following manner. As the table reverses from the return to the forward stroke, a command is transmitted to the feed gearbox motor M_2. Rotation of this motor is transmitted to any of the screws or rods of the crossrail, as described above, depending upon the positions of the feed engagement levers.

Shaft rotation and, consequently, the feed motion continue until the expanding strip of the friction clutch runs against a fixed stop and disengages the clutch. This stops the feed motion. Then a trip dog operates the table reversing limit switch at the beginning of the forward stroke and switches off the feed drive motor.

At the moment of table reversal from the forward to the return stroke, the feed mechanism is reset, or "charged". An impulse from the table reversing limit switch *starts feed gearbox rotation in the opposite direction.* The pawl slips over the ratchet wheel teeth and the output gear remains stationary. At the end of table reversal, when the trip dog runs off the table limit switch, the feed drive motor is switched off. Now the feed mechanism is ready for a new feed motion. This cycle is repeated for each full stroke (forward and return) of the table.

Positioning traverse of the tool heads is accomplished as follows. When the positioning push button on the pendent station is pressed, the feed drive motor M_2 is switched on but only in the direction for working feed. At the same time, solenoid *4* is energized. This engages worm wheel $58T$ with ratchet wheel $60T$ through jaw clutch C_2. Thus, rotation is transmitted from the motor through the worm gearing and output gear to the distributing shaft *II* and further as for working feeds. The friction clutch operates in the same way as previously described and stops rotating when the expanding strip runs against the fixed stop. Subsequently, the friction clutch slips and the pawl of ratchet wheel $60T$ slides over the teeth.

The rate of feed is set with handwheel *5*. Its rotation is transmitted through the gearing $\frac{19}{75}$ to adjustable stop *6*. This alters the angle between the adjustable and fixed stops, thereby setting the rate of feed. To prevent rotation when the mechanism is "charged", the adjustable stop is fixed by gear $15T$ and segment gear *7*.

In addition to the power travel of the tool heads, the feed gearbox also permits hand traverse in setting up the planer, obtained from a detachable crank handle and a dial for reading the length of travel.

The feed gearbox of the side tool head is similar in construction to the one described but has only two output shafts: for horizontal travel of the tool head slide and for vertical travel of the whole tool head along the housing.

In addition to planers with an electromechanical table drive, models are available with a hydraulic drive that also enables the forward and return stroke speeds of the table to be steplessly varied in wide ranges.

The hydraulic circuit of a planer made by the Rockford Machine Tool Co. (USA) is shown in Fig. 183.

This circuit is based upon variable-displacement speed control and closed oil circulation. This is accomplished by a variable-displacement pump P_{vd} with a maximum delivery of 450 or 650 litres per min and a design pressure of 75 kg per sq cm. The control system of the variable-displacement pump is supplied from pump P_1 with a delivery of 42 litres per min and a working pressure of 6.8 kg per sq cm. Pump P_2, with a delivery of 42 litres per min and working pressure of 17 kg per sq cm, supplies the control system of all the valves in the circuit. Pump P_3 has an independent motor drive and serves for replenishing the oil in the system and for producing a backpressure of 27 kg per sq cm.

Two relief valves, set for a pressure of 117 kg per sq cm, are mounted in the circuit of pump P_{vd} to relieve instantaneous overloads due to table reversal, as are two check valves for filling the pump circuit. In addition, there is a three-way two-position valve V_1 which operates in conjunction with the control system of pump P_{vd}, automatically connecting make-up pump P_3 with the suction side of pump P_{vd} during the forward and return strokes of the table. Upon acceleration or deceleration of table travel, this same valve disconnects the make-up pump from the suction side of pump P_{vd}, thereby avoiding vibration in the hydraulic system.

The planer table is reciprocated by two hydraulic cylinders, one of single- and the other of double-acting design. The effective area in the head end C_3 of the double-acting cylinder is equal to the sum of the effective areas of the single-acting cylinder C_1 and the rod end C_2 of the double-acting cylinder.

The connection of two cylinders in various combinations to the discharge end of the variable-displacement pump provides for three ranges of infinitely variable table speeds. These comprise the low range, in which oil is delivered to cylinders C_1 and C_2; medium range, in which only single-acting cylinder C_1 is connected to the pump; and the high range in which only rod end C_2 of the double-acting cylinder is receiving oil from the pump.

The speed is increased on the return stroke since oil is delivered simultaneously to the head end of the double-acting cylinder both from the pump and the single-acting cylinder.

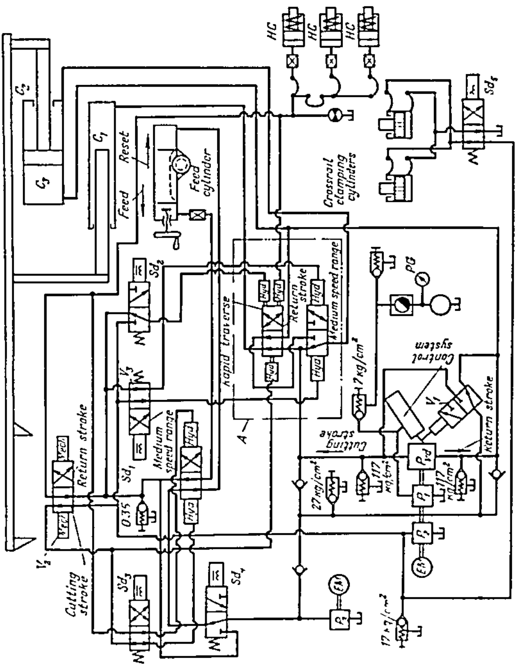


Fig. 183. Hydraulic circuit of a planer made by the Rockford Machine Tool Co. (USA)

During the forward stroke of the table, when operating in the low range of speeds, oil is delivered through control panel A to the rod end of the double-acting cylinder and to the single-acting cylinder. At the end of the forward stroke, valve V_2 is shifted by a cam dog to the return stroke position. Oil from valve V_2 is admitted to the hydraulic cylinders HC for lifting the cutting tools and shifts the four-way valve of control panel A to the rapid strokes position. At the same time, the direction of oil delivery from pump P_{ed} is changed. Oil from pump P_{ed} and from cylinder C_1 is delivered to cylinder C_3 and the table returns rapidly.

In operation in the medium speed range, solenoid Sd_1 of valve V_3 is energized and the three-way valve of control panel A is shifted to the medium position. At this oil is admitted only into hydraulic cylinder C_1, while both ends of the double acting cylinder are connected together and to the suction end of pump P_{ed}.

When solenoid Sd_1 is de-energized and solenoid Sd_2 is energized, oil under pressure is admitted to the large end of the four-way valve spool in panel A. This shifts the spool and fixes it in the high speeds position, regardless of the position of valve V_2. In this case, the forward strokes of the table will operate in the high speed range.

If solenoid Sd_3 is de-energized, tool feed will occur at the moment of table reversal from the return to the forward strokes. Feed will take place at the other end of the stroke if solenoid Sd_3 is energized.

The feed mechanism can be disengaged by means of solenoid Sd_4 when the planer is being set up.

Solenoid Sd_5 is interlocked with the crossrail elevating motor.

9-2. Attachments Extending the Processing Capacities of Planers

1. Convex cylindrical surfaces of circular profile can be planed by a simple device consisting of radial tie-rod *3* linked by pivot pins *2* to bracket *1* and to the tool head slide (Fig. 184). The vertical feed screw of the tool head is disengaged from the slide. In operation with this setup, the tool head saddle travels along the crossrail as usual. At the same time, the slide has a vertical motion due to the action of tie-rod *3*, and the tool planes a cylindrical surface.

2. It is impossible to cut helical grooves with a very large lead in ordinary milling machines. Such grooves can be made in a planer, using the attachment shown in Fig. 185*a*.

This device consists of centre stocks *1* mounted on the table; rod *3*, weighted on one end and clamped on work *2* with its other end; and inclined bar *4*. The upper end of the bar is secured to a housing and the lower end to the bed.

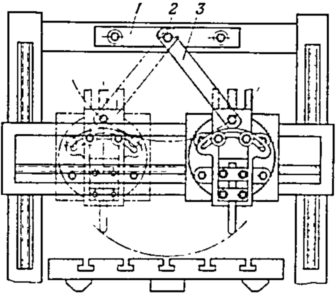


Fig. 184. Device for planing curved surfaces:
1—bracket, 2—pivot pins; 3—tie-rod

The lead of the groove being cut depends upon the inclination of this bar. The tool is selected to suit the profile of the groove. During the stroke of the table, rod *3*, first resting on the lower part of bar *4*, is gradually lifted, sliding along the bar, and turns the work clockwise through the required angle.

The blank can be rotated by other methods as well. Figure 185*b* shows an attachment in which pinion *1* and rack *2* are employed for this purpose. One end of the rack is linked through a roller with inclined bar *3*. Upon table travel, the rack moves crosswise and turns work *4* through an angle determined by the inclination of the bar.

3. Ruled surfaces of irregular profile can be planed with great accuracy using the simple tracer-controlled slide shown in Fig. 186.

The vertical feed screw of the tool head is replaced by a hydraulic cylinder with a piston. The cylinder is secured to slide *1* of the tool head and the piston rod to saddle *2* of the tool head. Bracket *3*, mounted on the saddle, carries the hydraulic tracer stylus. The template or pattern *4* is fastened on the crossrail by means of brackets *5*.

The operation of the tracer-controlled slide of a planer differs from that of the hydraulic circuit of a tracer-controlled milling machine (see Sec. 8-4) by its intermittent nature. In the planer, the tracer-controlled slide operates only at the moment of transverse feed of the tool During the cutting stroke

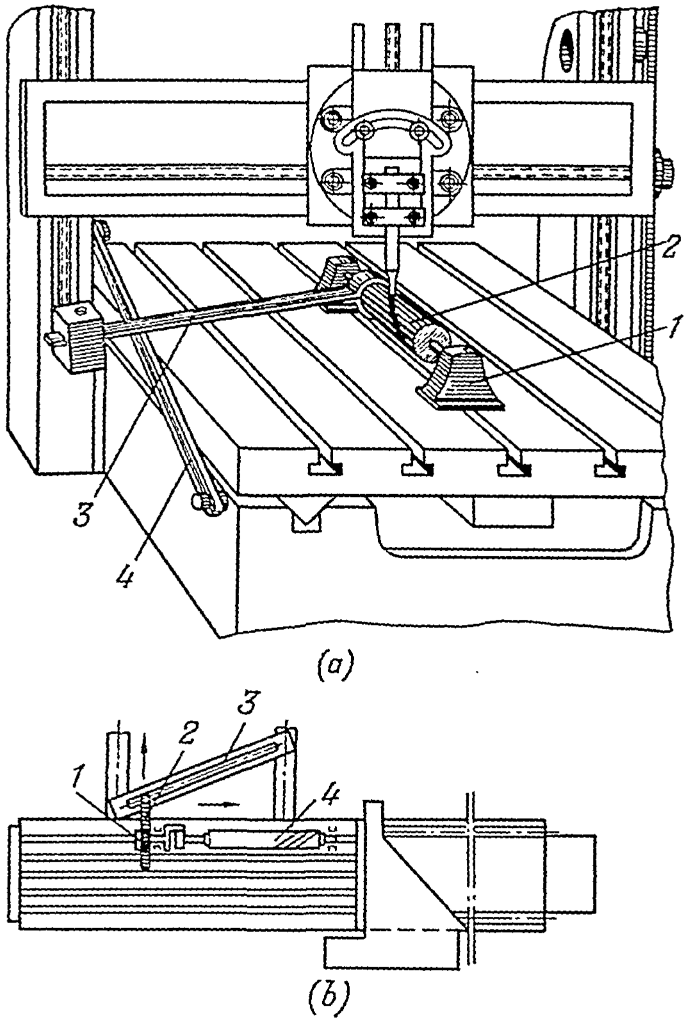


Fig. 185. Cutting helical grooves with a large lead in a planer

of the table, the tool head slide is rigidly secured to the saddle by hydraulic clamp *6*, controlled by the tool head clamping cylinder.

At the moment of table reversal from the return to the cutting stroke, a limit switch starts the cross feed motor (see Sec. 9-1). At the same time, solenoid Sd_1 of the two-position four-way valve V_1 is energized. This valve admits oil from the accumulator *Acc* and pump *P* to the rod end of clamping cylinder *6*. This unclamps the tool head slide. Cross feed of the tool head saddle occurs simultaneously. The tracer stylus moves along the template and sets the tool at the required height. At the beginning of the cutting stroke, just

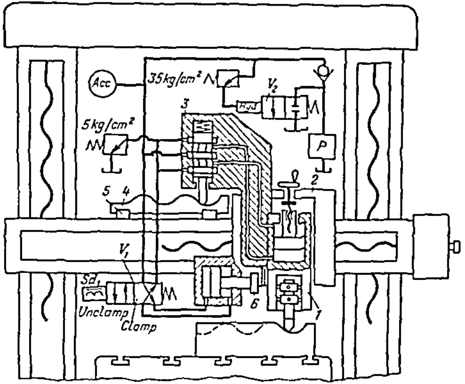


Fig. 186. Hydraulic tracer-controlled slide of a planer

before the tool starts the cut, solenoid Sd_1 is de-energized by means of limit switches mounted on the bed. As a result, oil from the accumulator and pump is admitted to the head end of the clamping cylinder. This clamps the slide and cutting begins. Due to the short period of actual operation of the hydraulic tracer slide and the fact that the cutting force is not carried by elements of the hydraulic system, as well as the provision of an accumulator and automatic unloading of the pump station, the power rating of the pump motor is only a fraction of that required for the tracer-controlled slide of an engine lathe. The accumulator is replenished with oil during the cutting and return strokes of the table, this operation being controlled by valve V_2 and another valve V which connect pump P to the tank when the accumulator is replenished.

4. The oil grooves on the ways of machine tools are usually chipped by hand with a cape chisel. This operation can be more efficiently performed in a planer equipped with a cutting head in place of the ordinary tool head.

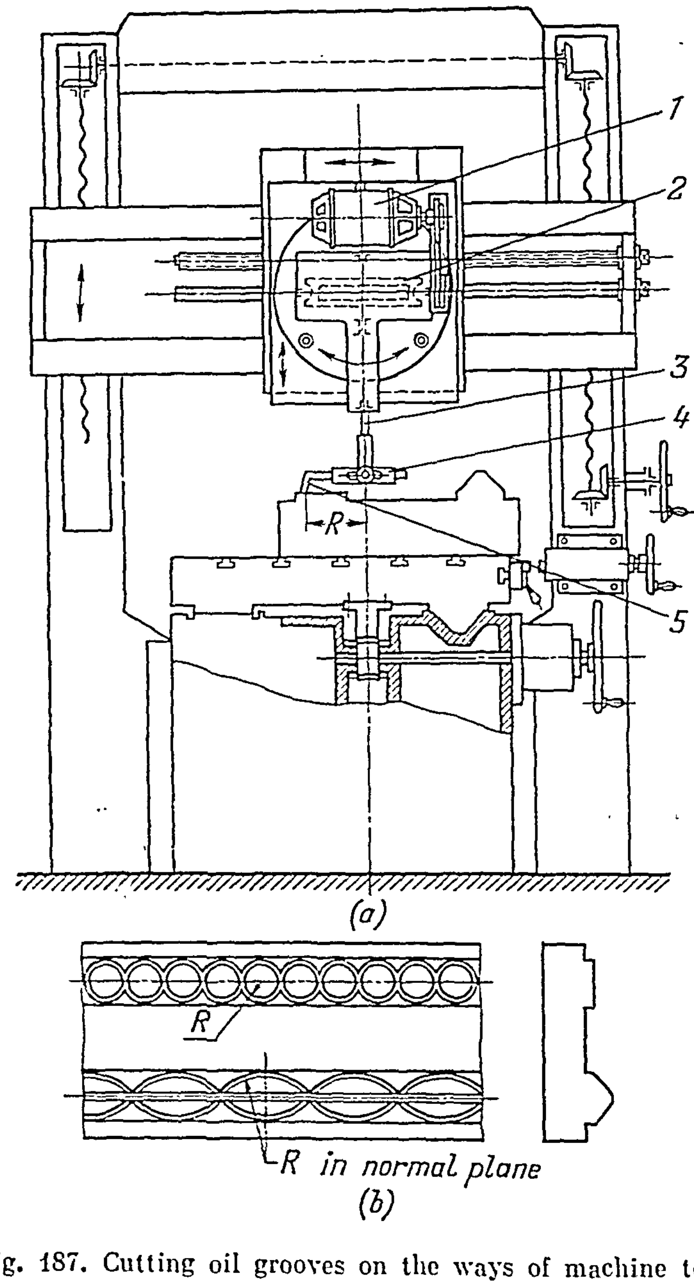


Fig. 187. Cutting oil grooves on the ways of machine tools:
(a) groove cutting attachment; (b) cut grooves

This attachment consists of motor *1* (Fig. 187), worm reducing gear *2* and spindle *3* with toolholder *4*. Tool *5* is clamped in the toolholder on an arm of a length equal to the radius of the grooves to be cut. When the motor is switched on the tool travels in a circle. As each circular groove is being cut, the table is stationary; it is advanced by an amount equal to the pitch of the grooves to cut the next groove. Grooves can be cut by this method on the faces of V-ways by swivelling the head to the required angle.

9-3. Various Types of Planers

In addition to the usual tool heads, planers may be equipped with grinding and milling heads.

Planers with grinding heads (Fig. 188) enable the work to be planed and ground in one setting so that finished surfaces of high accuracy and a fine surface finish are obtained in a single machine. These planers differ from those described previously only in that they have a grinding head *1*, additional protection *2* of the bed ways against abrasive dust and fine metal chips, and special shields *3* which protect the operator against splashing coolant during grinding operations.

The grinding head is mounted on an additional, usually the third, saddle on the crossrail, or it may be detachable and installed in place of the swivel slide (harp) of one of the standard tool heads. The wheel drive motor is built into the grinding head.

Planers with milling or milling and boring heads are intended for planing, milling and boring large workpieces. Milling heads may be mounted either on the crossrail or on the housings. Heads installed on the crossrail usually have cross feed (feed across the table); side milling heads can be positioned vertically along the housing.

Pit planers (Fig. 189) are used for planing the upper horizontal and inclined surfaces of high workpieces (for example, housings of rolling mill stands). The workpiece is set up on a plate arranged in a pit. The frame of the planer, comprising the crossrail and its carriages and carrying the tool heads, travels along beds at the sides of the pit. This constitutes the reciprocating primary cutting motion. The crossrail of such planers may have a travel up to 12 m on some models.

In the plate, or edge, planers (Fig 190) as in the pit planers, the cutting and feed motions are accomplished by a carriage travelling together with the tools along the plate being machined which is held rigidly to the stationary machine platen (table). Plate planers are intended for machining the edges of separate plates or stacks of plates up to 200 mm thick and up to 1,500 mm wide, or other work of the same overall size. The maximum planing length of this type of planer is 12 m.

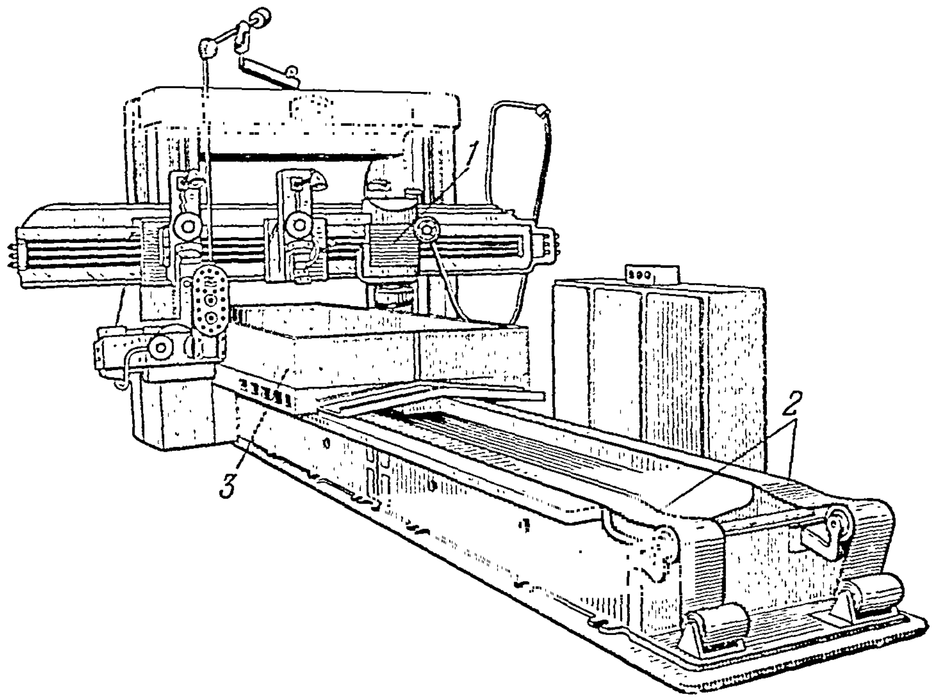


Fig. 188. Planer with a grinding head

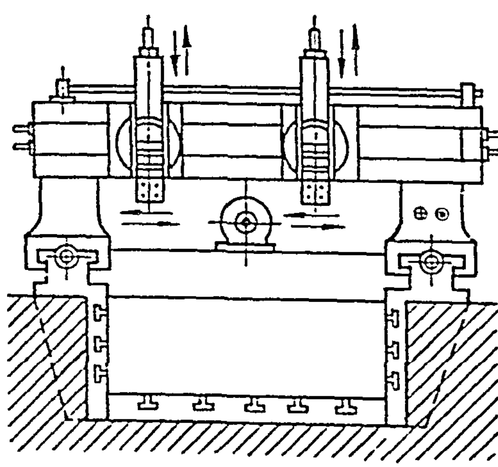


Fig. 189. Pit planer

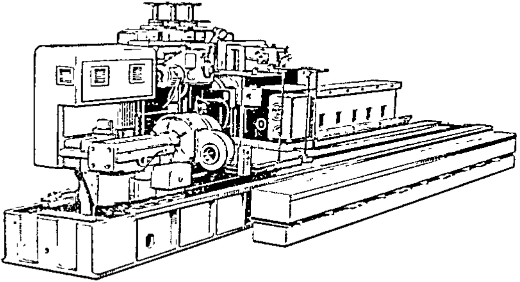


Fig. 190. Plate, or edge, planer

9-4. Shapers

Shapers are used for machining horizontal, vertical and inclined flat surfaces on small and medium-sized workpieces, for cutting straight slots and grooves, and much less frequently, for machining ruled surfaces of irregular profile.

In operating a shaper, the work is clamped on the overhanging table while the tool is clamped in the toolholder of the ram which has a horizontal reciprocating motion, as a rule, across the work. Either power or hand cross or vertical feeds can be transmitted to the table which travels crosswise along a rail and vertically with the rail along ways of the column.

The maximum stroke of the ram is the dimension which specifies the size of a shaper. Ram strokes may range from 200 to 2,400 mm in various models (see Table 26). Shapers with the longer ram strokes, from 1,500 mm and up, do not have a moving table. They are designed for roughing and finishing large, heavy work such as press frames and similar work handled in the heavy engineering industries. The work is clamped on a stationary foundation plate. The feed motion is obtained in a horizontal plane by travel of the column, and in a vertical plane by travel of the ram head along the column which can be swivelled through an angle of $\pm 45°$ (model 7M386) or $\pm 250°$ (model KY-74).

TABLE 26

Model	Maximum stroke of ram, mm	Ram strokes per min or ram speeds, m/min	Working surface of table, mm		Table or saddle travel, mm		Range of table or saddle feeds, mm per full stroke	Power of drive motor, kW	Net weight, kg approx.	Remarks
			top	side	horizontal	vertical				
7А311	200	53-212	200×200	220×150	250	150	0.1-1.2	0.8-1-1.4-1.5	600	With crank shaper mechanism
7А33	320	16-186	320×280	—	300	—	0.3-0.48	1.7-1.9-2.5-3	1,100	
7Б35	500	12.3-138	500×360	375×380	600	310	0.167-1.0	5.5	1,900	
7В35	500	13.2-150	500×360	415×435	500	310	0.15-0.9	5.5	2,000	Equipped with hydraulic tracer-control device
7В36	700	10.6-118	700×450	635×520	650	310	0.15-0.9	5.5	2,400	
7М36	700	3-48 m/min	750×700	—	700	320	0.25-5	7.5	3,100	With hydraulic drive; equipped with hydraulic tracer-control device
7М37	1,000	3-48 m/mim	1,000×560	—	800	400	0.5-5	10	4,400	
ГД-21	930	3-48 m/min	1,000×560	—	800	420	0.25-5	10	5,400	Hydraulic tracer-controlled type with two tool heads having 100-mm travel
7М386	1,600	5-30 m/min	—	—	3,000	1,500	0.3-12	29	48,000	
КУ-39	1,500	5-30 m/min	—	—	1,200	400	0.3-12.8	21	23,000	
КУ-39А	1,200	5-30 m/min	—	—	1,200	100	0.2-12.8	21	23,000	
КУ-74	2,400	5-25 m/min	—	—	8,000	2,000	0.3-12	29	108,000	

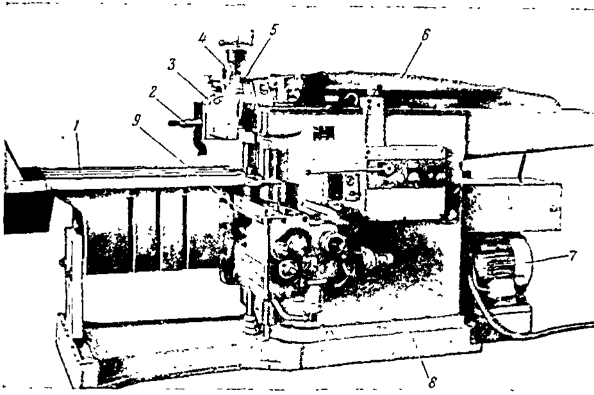


Fig 191 Shaper, model 7M37

In models КУ-39 and КУ-39А vertical feed is accomplished only by means of the tool head slide. A common type of shaper is shown in Fig. 191.

Horizontal ways, or guides, are provided on the top of cast column *8* along which ram *6* with the tool head travels. The tool head consists of swivel head *5*, tool slide *4* traversed vertically by a screw, clapper box *3* and tool block with tool post *2*.

Rail *9* can be adjusted vertically along the front ways of the column. Table *1* with its saddle is fed horizontally along the rail by the feed mechanism. A table support secures the table to the base to provide rigidity in operation.

In setting up the work the rail can be adjusted vertically to suit the height of the work. Ram reciprocation is powered by drive motor *7* either through a speed gearbox and slotted rocker arm crank mechanism or through a hydraulic drive.

TABLE 26

Model	Maximum stroke of ram, mm	Ram strokes per min or ram speeds, m/min	Working surface of table, mm		Table or saddle travel, mm		Range of table or saddle feeds, mm per full stroke	Power of drive motor, kW	Net weight, kg approx.	Remarks
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7Б35	500	12.3-138	500×360	375×380	600	310	0.167-1.0	5.5	1,900	
7B35	500	13.2-150	500×360	415×435	500	310	0.15-0.9	5.5	2,000	Equipped with hydraulic tracer-control device
7B36	700	10.6-118	700×450	635×520	650	310	0.15-0.9	5.5	2,400	
7M36	700	3-48 m/min	750×700	—	700	320	0.25-5	7.5	3,100	With hydraulic drive; equipped with hydraulic tracer-control device
7M37	1,000	3-48 m/mim	1,000×560	—	800	400	0.5-5	10	4,400	
ГД-21	930	3-48 m/min	1,000×560	—	800	420	0.25-5	10	5,400	Hydraulic tracer-controlled type with two tool heads having 100-mm travel
7M386	1,600	5-30 m/min	—	—	3,000	1,500	0.3-12	29	48,000	
КУ-39	1,500	5-30 m/min	—	—	1,200	400	0.3-12.8	21	23,000	
КУ-39А	1,200	5-30 m/min	—	—	1,200	100	0.2-12.8	21	23,000	
КУ-74	2,400	5-25 m/min	—	—	8,000	2,000	0.3-12	29	108,000	

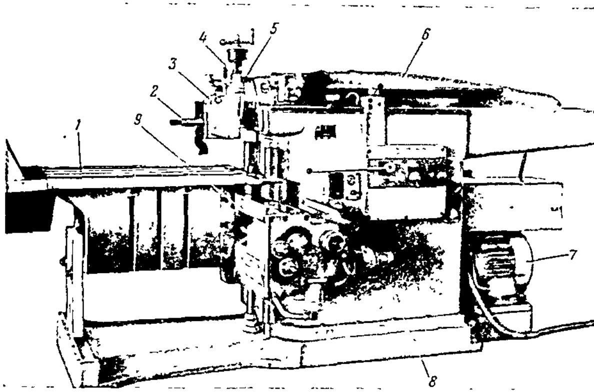

Fig. 191. Shaper, model 7M37

In models КУ-39 and КУ-39А vertical feed is accomplished only by means of the tool head slide. A common type of shaper is shown in Fig. 191.

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In setting up the work the rail can be adjusted vertically to suit the height of the work. Ram reciprocation is powered by drive motor *7* either through a speed gearbox and slotted rocker arm crank mechanism or through a hydraulic drive.

TABLE 26

Model	Maximum stroke of ram, mm	Ram strokes per min or ram speeds, m/min	Working surface of table, mm		Table or saddle travel, mm		Range of table or saddle feeds, mm per full stroke	Power of drive motor, kW	Net weight, kg approx.	Remarks
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7Б35	500	12.3-138	500×360	375×380	600	310	0.167-1.0	5.5	1,900	
7B35	500	13.2-150	500×360	415×435	500	310	0.15-0.9	5.5	2,000	Equipped with hydraulic tracer-control device
7B36	700	10.6-118	700×450	635×520	650	310	0.15-0.9	5.5	2,400	
7M36	700	3-48 m/min	750×700	—	700	320	0.25-5	7.5	3,100	With hydraulic drive; equipped with hydraulic tracer-control device
7M37	1,000	3-48 m/min	1,000×560	—	800	400	0.5-5	10	4,400	
ГД-21	930	3-48 m/min	1,000×560	—	800	420	0.25-5	10	5,400	Hydraulic tracer-controlled type with two tool heads having 100-mm travel
7M386	1,600	5-30 m/min	—	—	3,000	1,500	0.3-12	29	48,000	
КУ-39	1,500	5-30 m/min	—	—	1,200	400	0.3-12.8	21	23,000	
КУ-39А	1,200	5-30 m/min	—	—	1,200	100	0.2-12.8	21	23,000	
КУ-74	2,400	5-25 m/min	—	—	8,000	2,000	0.3-12	29	108,000	

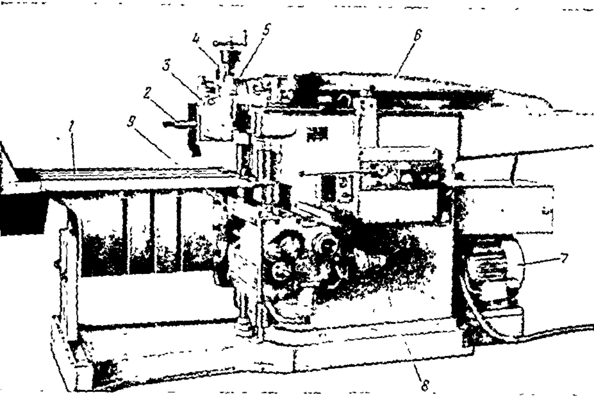


Fig. 191 Shaper, model 7M37

In models KY-39 and KY-39A vertical feed is accomplished only by means of the tool head slide A common type of shaper is shown in Fig. 191.

[illegible] d on the top of cast column 8 [illegible] The tool head consists of swivel [illegible] vertically by a screw, clapper box 3 and tool [illegible] with tool post 2.

Rail 9 can be adjusted vertically along the front ways of the column. Table 1 with its saddle is fed horizontally along the rail by the feed mechanism. A table support secures the table to the base to provide rigidity in operation.

In setting up the work the rail can be adjusted vertically to suit the height of the work. Ram reciprocation is powered by drive motor 7 either through a speed gearbox and slotted rocker arm crank mechanism or through a hydraulic drive.

TABLE 26

Model	Maximum stroke of ram, mm	Ram strokes per min or ram speeds, m/min	Working surface of table, mm		Table or saddle travel, mm		Range of table or saddle feeds, mm per full stroke	Power of drive motor, kW	Net weight, kg approx.	Remarks
			top	side	horizontal	vertical				
7A311	200	53-212	200×200	220×150	250	150	0.1-1.2	0.8-1-1.4-1.5	600	With crank shaper mechanism
7A33	320	16-186	320×280	—	300	—	0.3-0.48	1.7-1.9-2.5-3	1,100	
7Б35	500	12.3-138	500×360	375×380	600	310	0.167-1.0	5.5	1,900	
7B35	500	13.2-150	500×360	415×435	500	310	0.15-0.9	5.5	2,000	Equipped with hydraulic tracer-control device
7B36	700	10.6-118	700×450	635×520	650	310	0.15-0.9	5.5	2,400	
7M36	700	3-48 m/min	750×700	—	700	320	0.25-5	7.5	3,100	With hydraulic drive; equipped with hydraulic tracer-control device
7M37	1,000	3-48 m/mim	1,000×560	—	800	400	0.5-5	10	4,400	
ГД-21	930	3-48 m/min	1,000×560	—	800	420	0.25-5	10	5,400	Hydraulic tracer-controlled type with two tool heads having 100-mm travel
7M386	1,600	5-30 m/min	—	—	3,000	1,500	0.3-12	29	48,000	
KУ-39	1,500	5-30 m/min	—	—	1,200	400	0.3-12.8	21	23,000	
KУ-39A	1,200	5-30 m/min	—	—	1,200	100	0.2-12.8	21	23,000	
KУ-74	2,400	5-25 m/min	—	—	8,000	2,000	0.3-12	29	108,000	

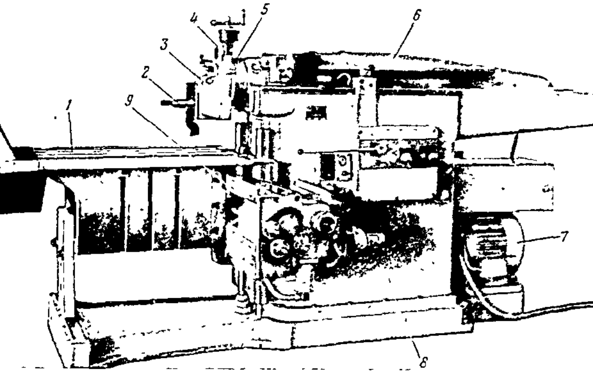


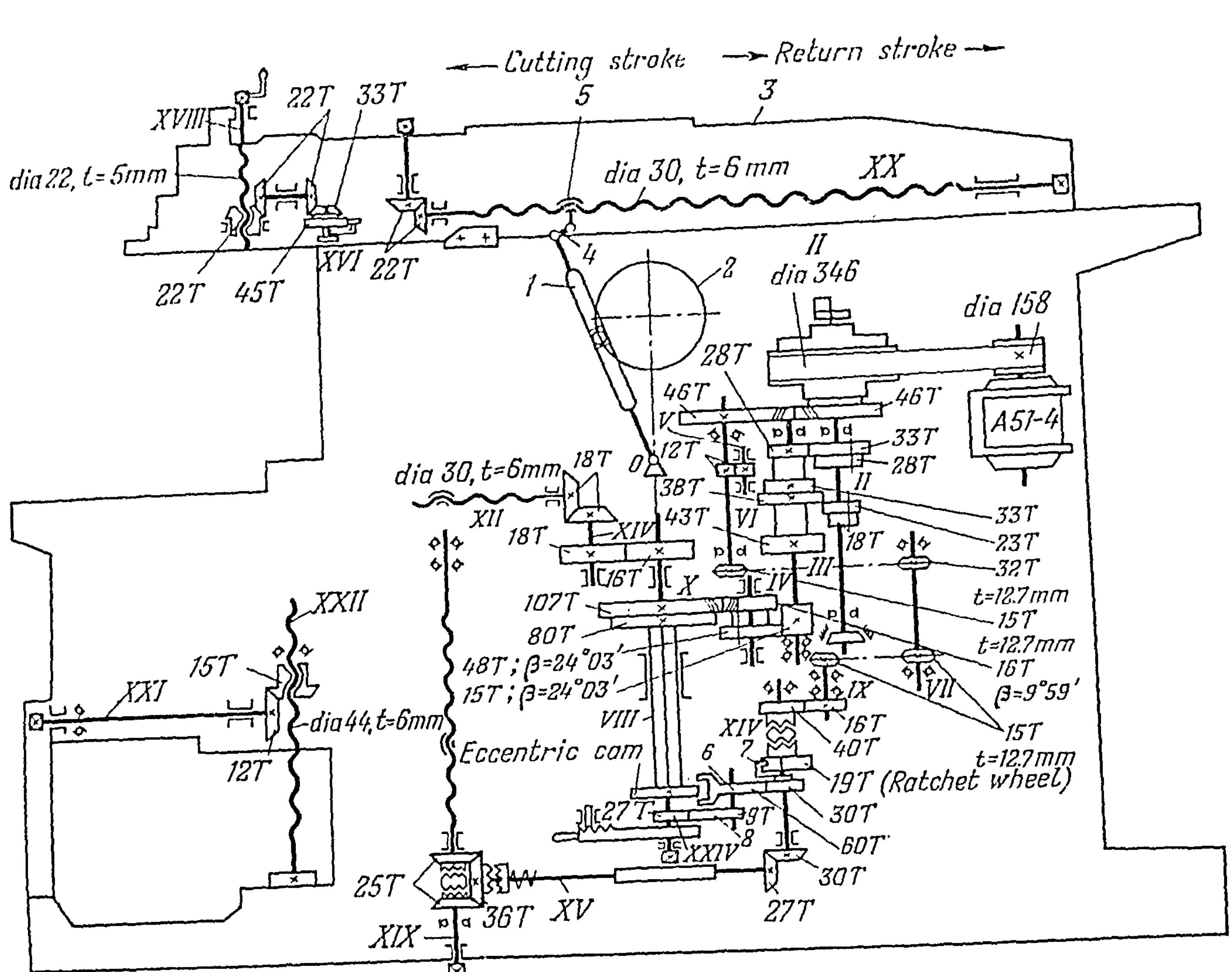
Fig. 191. Shaper, model 7M37

In models KY-39 and KY-39A vertical feed is accomplished only by means of the tool head slide. A common type of shaper is shown in Fig. 191.

Horizontal ways, or guides, are provided on the top of cast column *8* along which ram *6* with the tool head travels. The tool head consists of swivel head *5*, tool slide *4* traversed vertically by a screw, clapper box *3* and tool block with tool post *2*.

Rail *9* can be adjusted vertically along the front ways of the column. Table *1* with its saddle is fed horizontally along the rail by the feed mechanism. A table support secures the table to the base to provide rigidity in operation.

In setting up the work the rail can be adjusted vertically to suit the height of the work. Ram reciprocation is powered by drive motor *7* either through a speed gearbox and slotted rocker arm crank mechanism or through a hydraulic drive.



of the model 7Б35 shaper

The gearing diagram of the crank-drive shaper, model 7B35, is shown in Fig. 192. Slotted rocker arm *1* is linked to crank disk (bull gear) *2* carrying the crankpin that can be adjusted radially along the face of the disk to change the length of the stroke of ram *3*. The crankpin fits into the sliding block. Upon rotation of the crank disk, the sliding block travels in the slot of rocker arm *1* which oscillates on pivot bearing O arranged below the crank disk. The upper end of the rocker arm is connected by link *4* to the ram through a screw XX and nut *5*. In its oscillation, the rocker arm imparts the reciprocating motion to the ram. This motion consists of the forward (cutting) stroke and the more rapid return stroke.

The position of the stroke (or the shaping zone) can be adjusted by changing the position of nut *5* on screw XX (by rotating the screw).

Though the crank disk rotates at uniform speed, the speed of the motion transmitted to the ram by the rocker arm will not be uniform.

The velocity of the crankpin (Fig. 193) is

$$v_1 = \frac{2\pi rn}{1{,}000} \text{ m per min} \tag{21}$$

where r = radius of the crankpin, mm

n = rotational speed of the crank disk, rpm.

The peripheral velocity of the sliding block (see $\triangle\, abc$) is

$$v_2 = v_1 \cos(\alpha - \gamma) \tag{22}$$

where the reference point for the angle α of crankpin rotation is taken on the radius O_1d, and that for the angle γ of rocker arm inclination is on the radius OO_1.

The peripheral velocity of the driving pin of the rocker arm at point A is

$$v_{ra} = v_2 \frac{R}{Oa}$$

After expressing Oa in terms of e and r and substituting (see $\triangle\, Oad$), we can write

$$v_{ra} = v_2 \frac{R\cos\gamma}{e \pm r\cos\alpha} \tag{23}$$

From $\triangle\, Oad$

$$\gamma = \arctan\frac{r\sin\alpha}{e \mp r\cos\alpha} \tag{24}$$

The speed of the ram can be determined with sufficient accuracy for practical purposes from $\triangle\, ABC$:

$$v_r = v_{ra}\cos\gamma \tag{25}$$

Substituting equations (23), (22) and (21) into equation (25), and expressing the value e through L (ram stroke), using the similar triangles $\triangle\, OO_1D$ and

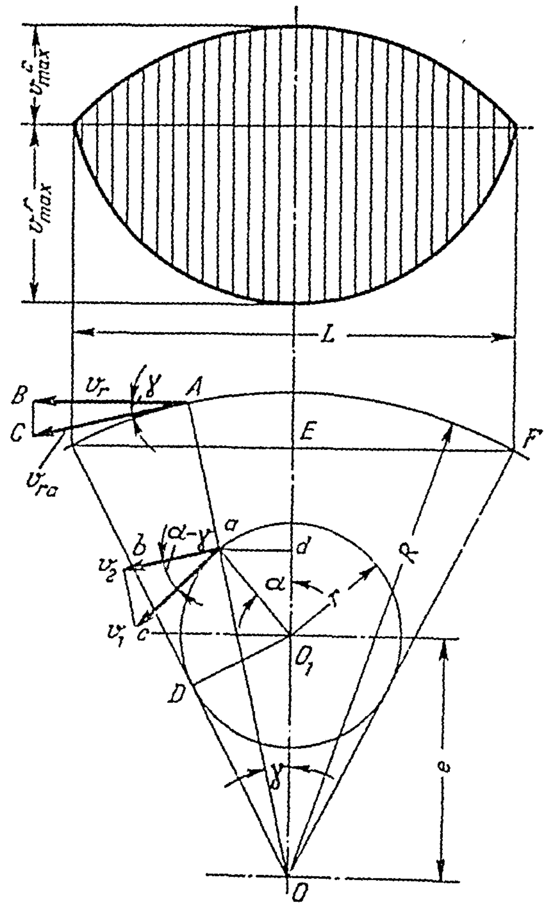


Fig. 193. Ram velocity diagram of a crank shaper

△ OEF, we obtain

$$v_r = \frac{2\pi nRL\cos^2\gamma\cos(\alpha-\gamma)}{1{,}000\,(2R+L\cos\alpha)} \text{ m per min} \tag{26}$$

It follows from equation (26) that since the angles α and γ are not constant during the cutting and return strokes, the ram speed will vary as shown in Fig. 193.

The maximum speed of ram travel in the cutting stroke is at $\alpha = \gamma = 0$ and is

$$v^c_{max} = \frac{2\pi nRL}{1{,}000\,(2R+L)} \text{ m per min} \tag{27}$$

The maximum speed of ram travel in the return stroke is at $a = 180°$ and $\gamma = 0$ and is

$$v^r_{max} = \frac{2\pi nRL}{1{,}000\,(2R-L)} \text{ m per min} \tag{28}$$

The mean cutting speed v_m during the full stroke (cutting and return strokes), in which the travel is $2L$, is

$$v_m = \frac{2Ln}{1{,}000} \text{ m per min} \tag{29}$$

Rotation is transmitted to shaft VIII of the crank disk (Fig. 192) through a speed gearbox providing eight steps of speed for a constant-speed drive motor. Rotation is transmitted from the motor through a V-belt drive and friction clutch to shaft *II* which carries two sliding double cluster gears controlled from a single lever. Various engagements of these gears provide shaft *III* with four speed steps. Integral with this shaft is a long helical gear 15*T* (module 4 mm) which transmits rotation to the double cluster gear of the countergearing, mounted freely on stationary axle *IV*. This cluster gear transmits rotation to the corresponding gear rim of the crank mechanism, the larger gear of the countergearing remaining in mesh with the long gear of shaft *III* regardless of the position of the countergearing. Thus, the crank disk obtains eight speeds of rotation.

The feed motion is transmitted to the table from an eccentric cam mounted on the crank disk shaft *VIII*. In its rotation, the eccentric cam rotates gear 30*T* by means of the roller of sector lever *6*. Gear 30*T* is linked to the drive member of pawl *7* which engages ratchet wheel 19*T*. This ratchet wheel is linked to shaft *XIV* through a jaw clutch. Shaft *XIV* is linked through bevel gearing to the telescopic feed shaft *XV* which transmits the feed motion to the table during the return stroke of the ram. Sector lever *6* is returned by a spring. During this motion, pawl *7* slips over the ratchet teeth.

The rate of feed is determined by the amplitude of oscillation of sector lever *6*. *This can be limited by segment gear 8 and gear 27T mounted on* a rotary housing.

Rapid table traverse is obtained from gear 16*T* on shaft *IX* which meshes with gear 40*T* freely mounted on shaft *XIV*. Rapid traverse is engaged by shifting the jaw clutch, which is disengaged from ratchet wheel 19*T* and engaged with gear 40*T*.

A smoother stroke and more uniform speed is obtained with a hydraulically driven ram than with the crank drive described above. Moreover, ram speeds are infinitely variable and the most expedient cutting speed can be selected for each job. The hydraulic circuit of the model 7M36 shaper is shown in Fig. 194.

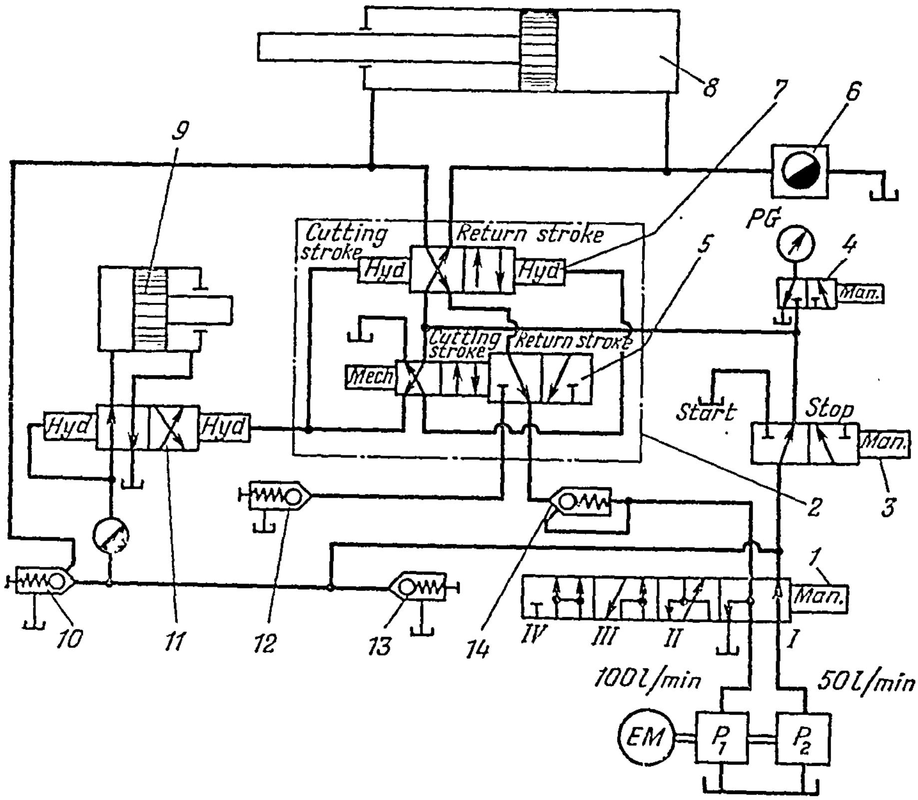


Fig. 194. Hydraulic circuit of the model 7M36 shaper

This circuit is based on the principle of combined speed variation. This leads to a negligible power loss, from the throttling of the oil, over the whole range of speeds.

Oil is delivered from the two-volume, low- and high-pressure pump P_1-P_2 to the four-position five-way speed-range valve *1*, and further through the reversing control panel *2* to the hydraulic cylinder *8* of the shaper ram. Such pumps are usually termed "double pump and combination valve units" and, depending upon which pump or their combination is connected to the ram cylinder, four ranges of ram cylinder piston speeds are obtained.

Speed range I is obtained when only the low-volume pump P_2 is connected to the cylinder, the discharge from the high-volume pump P_1 being returned to the tank. For speed range II, pump P_1 is connected to the cylinder and the discharge from pump P_2 is returned to the tank. Both pumps are connected to the cylinder for speed range III. Speed range IV, comprising the highest speeds, employs the differential features of a single-end rod cylinder

(see Part Four), in addition to the combined deliveries of the two pumps, i.e., both pumps are connected to both ends of the cylinder during the cutting stroke.

During the cutting stroke of the ram, the working fluid is delivered from valve *1* through START-STOP valve *3* and pilot-operated valve *7* to the head end of ram cylinder *8*. From the rod end of this cylinder, oil is returned through reversing valve *7* and further through pilot valve *5*, backpressure valve *14* and valve *1* to the tank.

Reversing is accomplished by cam dogs which shift valve *5* to the return stroke position. During the return stroke, oil from starting valve *3* passes through valve *7* into the rod end of hydraulic cylinder *8*. Oil from the head end drains to the tank through valves *7* and *5* and backpressure valve *12*, bypassing valve *1*.

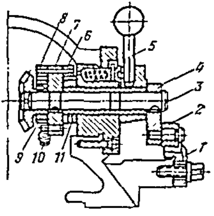


Fig. 195. Tool slide vertical feed mechanism of the model 7Б35 shaper

Stepless speed variation in each range is accomplished by the use of flow-control valve *6* connected in parallel with the head end of cylinder *8*. The system is protected against overloads by relief valve *13*. Valve *10* of the reversing system, controlled by the pressure in the rod end of the ram cylinder, opens at the moment of ram reversal from the cutting to the return stroke and reduces the pressure in the head end. This avoids an excessive rise of pressure in the rod end due to the combined action of the inertia forces of the ram and the pressure in the head end.

The feed motion is obtained from hydraulic feed cylinder *9*, automatically operated by valve *11*.

Rapid positioning traverse of the table in the horizontal and vertical directions is powered from a separate motor mounted on the rail. The pressure in the hydraulic system is indicated by pressure gauge *PG* which is connected to the circuit by valve *4*.

Vertical power feed of the tool slide of a shaper is effected by a ratchet mechanism mounted in the ram and operated by a trip dog at the end of the return stroke of the ram. The vertical feed mechanism of the tool slide on the model 7Б35 shaper is shown in Fig. 195. At the end of the return stroke of the ram, roller *2* of lever *4* runs up on trip dog *1* secured by screws on the column of the shaper. At this, shaft *3* turns together with lever *7* carrying pawl *8* of ratchet wheel *9* which is thus turned. The ratchet wheel is secured to and turns with a bevel gear transmitting rotation to the feed screw of the tool slide. The pawl is reset by the action of spring *10*. The rate of feed is

determined by the number of teeth on the ratchet wheel engaged by the pawl during each full stroke of the ram. This is varied by means of disk *11* on which a flat is milled. The pawl engages the ratchet wheel when the tooth of strip *6*, rigidly fastened to the pawl, runs up on the flat of the disk. The rate of feed is set by turning disk *11* with lever *5*. This sets the number of teeth engaged by the pawl in its stroke.

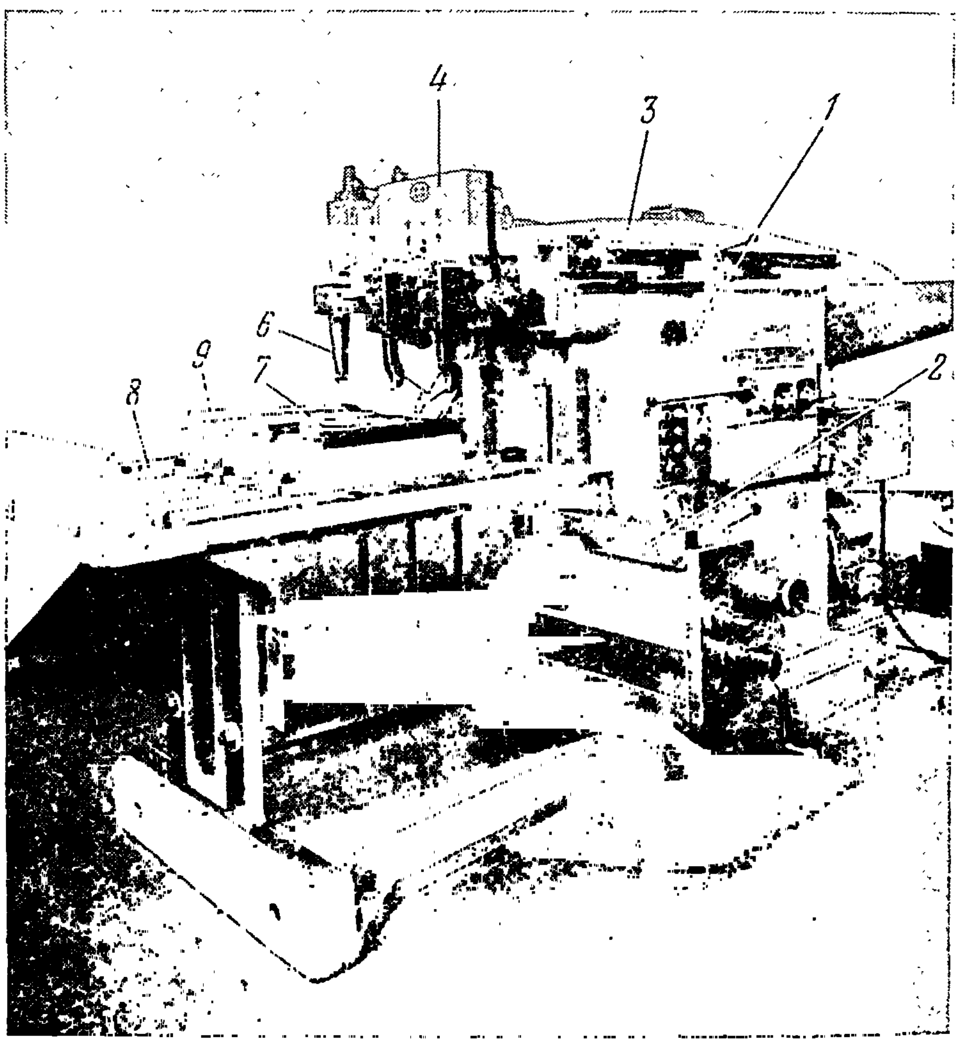


Fig. 196. Hydraulic tracer-controlled shaper, model ГД-21:
1—column; *2*—rail; *3*—ram; *4*—tracer-controlled slide; *5*—single-point tools; *6*—tracer stylus; *7*—work; *8*—table; *9*—template

9-5. Attachments Extending the Processing Capacities of Shapers

1. Grinding and milling can also be performed on a shaper if a milling or grinding head is mounted on the ram in place of the tool head. Such attachments can usually be swivelled through 360°, enabling surfaces arranged at various angles to be ground or milled.

2. Blanks for parts of complex shape can be machined on a shaper equipped with a hydraulic tracer-controlled device (models 7B35 and ГД-21). The hydraulic tracer-controlled shaper, model ГД-21 (Fig. 196), can machine contoured surfaces in which the elements are inclined up to 25° in the transverse direction. Three-dimensional tracing is performed by a single-coordinate servomechanism with a four-edge tracer valve (see Sec. 8-4). The hydraulic tracer-controlled slide of the machine carries two single-point tools at an adjustable distance from each other. This enables two workpieces to be machined simultaneously to a single template. The hydraulic tracer-controlled slide can be replaced by an ordinary tool head, in which case the shaper can operate as a universal shaper with a hydraulic drive as described in the preceding section.

3. The ram of a shaper develops less pulling force on the return stroke than on the forward cutting stroke. This force, however, is sufficient to perform semifinish and finish shaping operations. If chips are removed not only on the cutting stroke, but on the return stroke as well, the output of the shaper can be increased by from 30 to 40 per cent.

Figure 197 illustrates the operation of a double-cut tool head which can be installed in place of the ordinary one. The tool head consists of oscillating toolholder *1* in which tools *2* and *3* for the forward and return strokes are clamped. During the forward stroke, the toolholder is held by the action

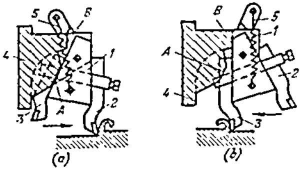


Fig. 197. Operation of a double-cut tool head
(a) forward stroke, (b) return stroke

determined by the number of teeth on the ratchet wheel engaged by the pawl during each full stroke of the ram. This is varied by means of disk *11* on which a flat is milled. The pawl engages the ratchet wheel when the tooth of strip *6*, rigidly fastened to the pawl, runs up on the flat of the disk. The rate of feed is set by turning disk *11* with lever *5*. This sets the number of teeth engaged by the pawl in its stroke.

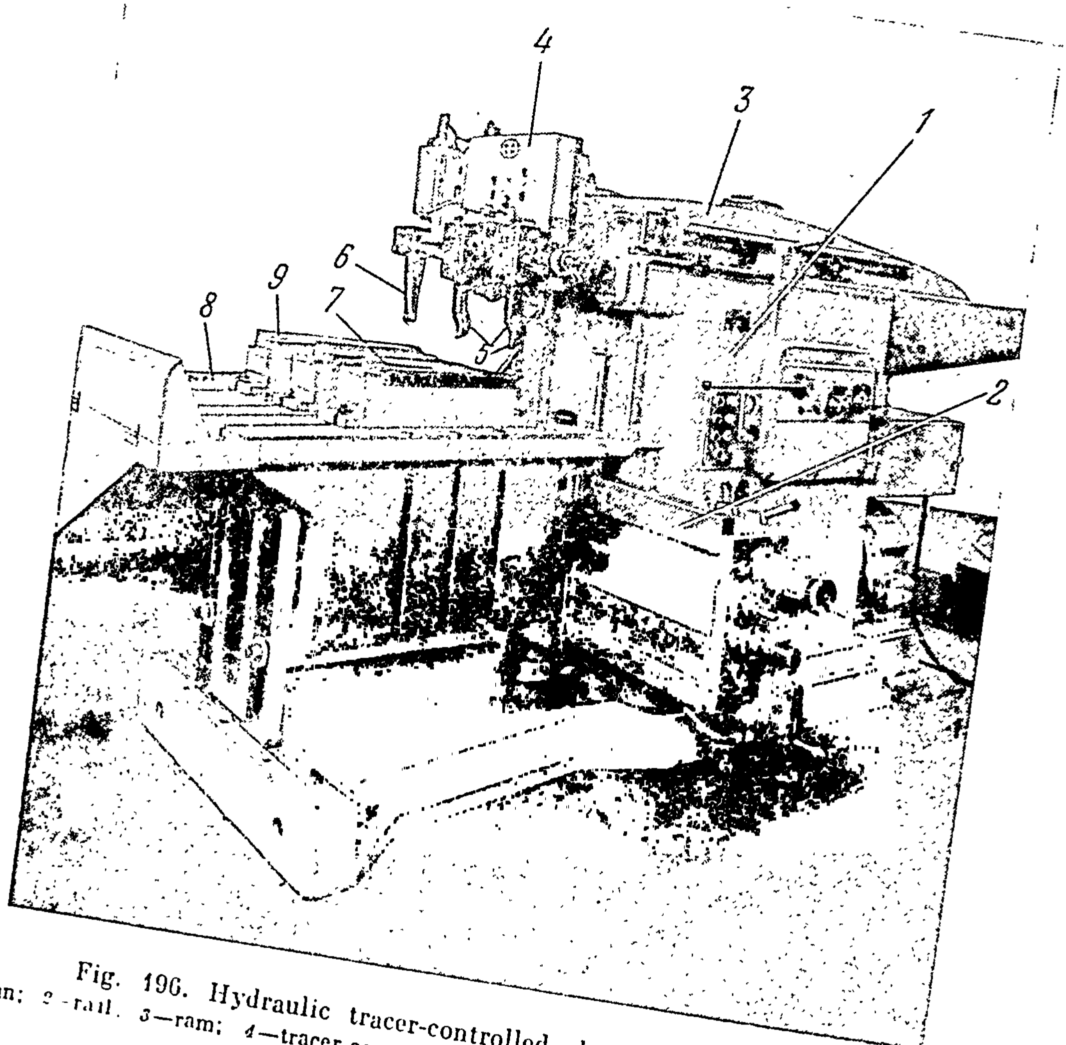


Fig. 196. Hydraulic tracer-controlled shaper, model ГД-21:
olumn; 2-rail, 3—ram; 4—tracer-controlled slide; 5—single-point tools; 6—tracer stylus; 7—work; 8—table; 9—template

9-5. Attachments Extending the Processing Capacities of Shapers

1. Grinding and milling can also be performed on a shaper if a milling or grinding head is mounted on the ram in place of the tool head. Such attachments can usually be swivelled through 360°, enabling surfaces arranged at various angles to be ground or milled.

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Figure 197 illustrates the operation of a double-cut tool head which can be installed in place of the ordinary one. The tool head consists of oscillating toolholder *1* in which tools *2* and *3* for the forward and return strokes are clamped. During the forward stroke, the toolholder is held by the action

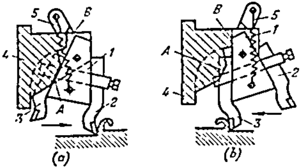


Fig. 197. Operation of a double-cut tool head:
(a) forward stroke; (b) return stroke

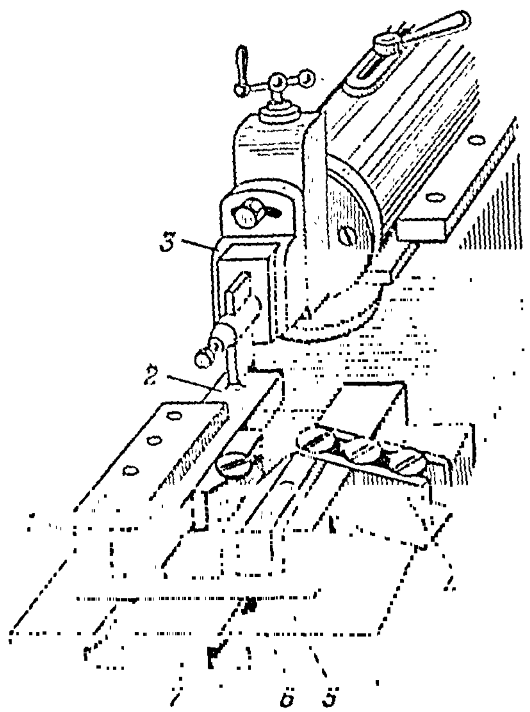


Fig. 198. Thread-rolling attachment on a shaper

of spring *5* to supporting surface *A* on body *4* of the tool head. During the return stroke, the toolholder is held to supporting surface *B* of the body. The toolholder is switched over at the end of each stroke by means of trip dogs and tie-rods. During the return stroke of the ram the horizontal component of the cutting force is directed toward the column. Since it is held by the cutting force against the bearing surfaces of the column ways, the table is subject to less deflection. This has a favourable effect on the accuracy with which operations are performed.

4. The thread of screws from 3 to 6 mm in diameter can be rolled by flat dies in a shaper using a special attachment (Fig. 198) mounted on the shaper table. Slide *2*, linked to toolholder *3*, reciprocates in body *1* of the attachment. Flat die *7* is fastened to this reciprocating slide. The other flat die *6* is secured in die holder *5* of the attachment. This die has crosswise adjustment. The bolt or screw blanks are loaded into feeding mechanism (or magazine) *4* by hand or by means of a mechanical loader. One blank is fed out on each full stroke of the slide. After being started, the blank is rolled by moving die *7* along stationary die *6* so that the thread is formed.

5. Shapers can also be employed for broaching operations. The broach can be clamped on the ram or it can be mounted on the shaper table. In the latter case, the work is held in a fixture which is secured on the front face of the ram in place of the tool slide.

9-6. Slotters

The main purpose of slotters is to machine flat and contoured ruled surfaces, slots and grooves, as well as dies of various types.

Slotters differ from shapers having tools reciprocating in a horizontal plane in that their tools reciprocate in a vertical plane which is square to

the working surface of the table or setting-up plate. Since the type of motion of slotters is the same as in shapers, the former are frequently called vertical shapers.

The feed motion in a slotter is intermittent *(periodical)*, and is effected by longitudinal, cross or rotary feed of the table. The main dimensions of a slotter are the *maximum stroke of the ram and the table diameter.* The latter determines the maximum size of work accommodated by the given shaper. Soviet machine tool plants produce slotters with a maximum ram stroke ranging from 100 to 1,600 mm and table diameter from 240 to 1,600 mm (Table 27).

The ram of an up-to-date slotter is reciprocated by either a mechanical or hydraulic drive.

The gearing diagram of the crank-drive slotter, model 7A412, is shown in Fig. 199*b*.

The model 7A412 slotter differs from the previously considered crank shaper in that its ram is driven through a rotating arm. This means that its axis of rotation is arranged between the axis of the crank disk and the ram (Fig. 200).

The instantaneous velocity of the ram is expressed by an equation similar to equation (26). Thus

$$v_r = \frac{2\pi nRL \cos^2 \gamma \cos(\alpha - \gamma)}{1{,}000\,(2R + L \cos \alpha)} \text{ m per min} \tag{30}$$

The *maximum speeds of the ram on the cutting and return strokes* are determined by equations (27), (28) and (29).

The four-speed induction motor of the slotter *(Fig. 199b)*, rated at 0.8/1.0/1.4/1.5 kW at the four speeds 700/900/1,350/2,800 rpm, drives shaft *I* through a belt transmission and a friction clutch. Gear 19*T*, mounted on shaft *I*, meshes with the bull gear 100*T*. The friction clutch is interlocked through a tie-rod with brake *B*. The plunger-type lubricating pump is driven by eccentric cam *1*

In the guides of bull gear 100*T* is the crankpin with bull gear block *2*. Rotating together with the crankpin and bull gear, the sliding block travels in the slot of the rocker arm effecting its oscillation about pivot pin *O*. The motion of the rocker arm is transmitted by link *4* to the ram which is an aluminium alloy casting The tool head mounted at the lower end of the ram *can be swivelled* 90° *in either direction*. The position of the ram stroke (or slotting zone) can be adjusted by turning screw *XX*.

In addition to vertical surfaces, the slotter can also machine surfaces inclined at an angle of up to 6° from the vertical This is done by tilting the ram about pivot pin O_1 using setting and clamping screws *5*

The length of the ram stroke is set by rotating screw *XVII* which is driven from shaft *XVI*, on whose square shank a cran[illegible]dle is put.

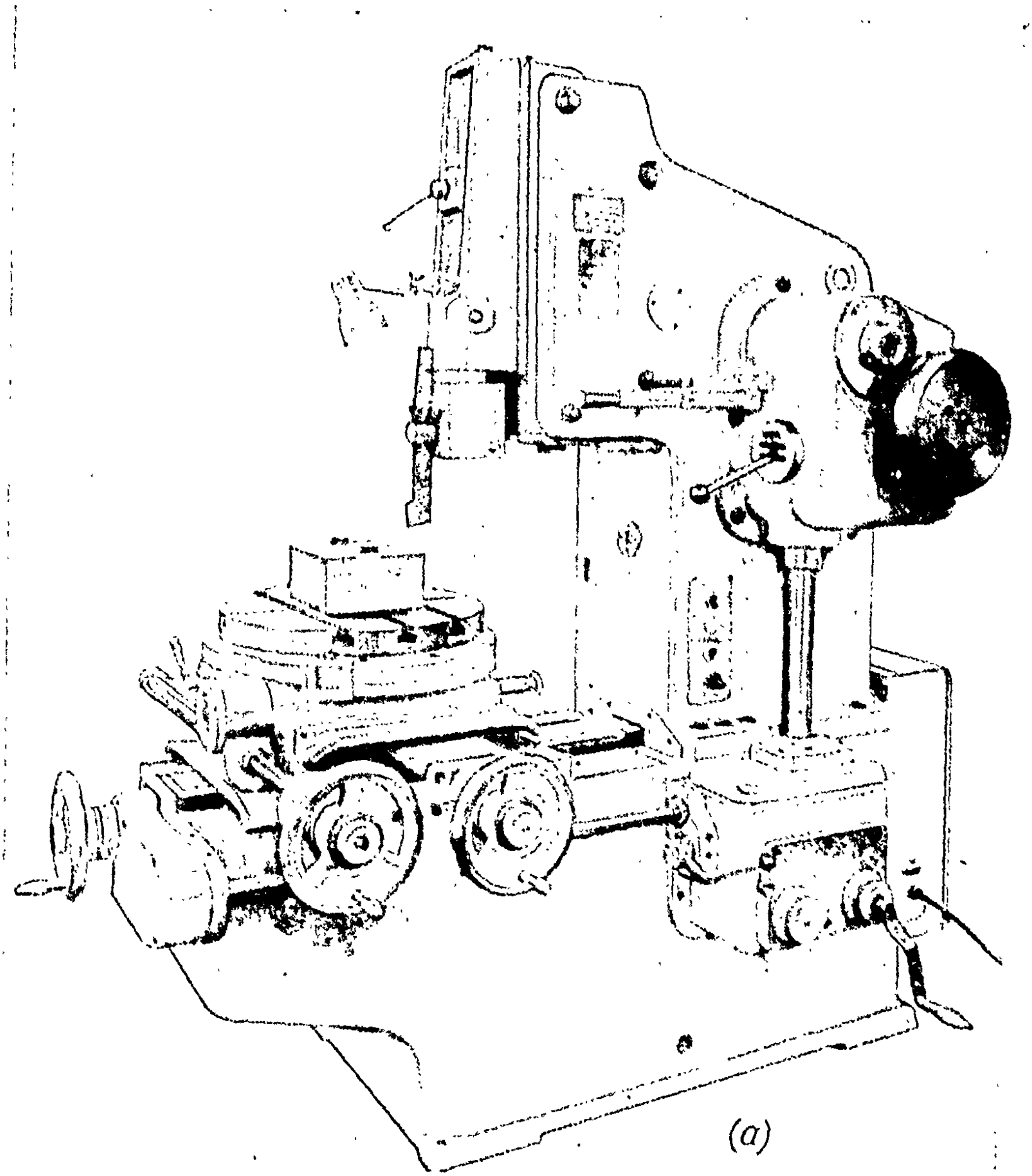
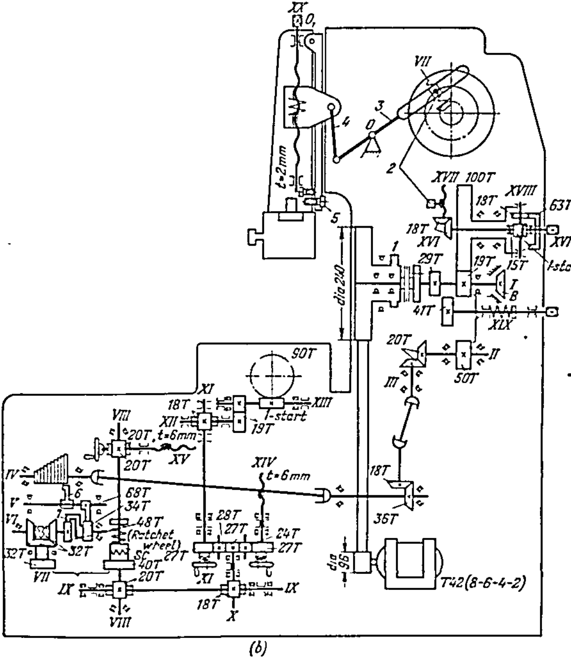


Fig. 199. Slotter, model 7A420 (a), and the



(b)

gearing diagram of the model 7A412 slotter (b)

TABLE 27

Items	Models					
	7A412	7A420	7M430	7M450	745M	747M
Maximum stroke of ram, mm	100	200	320	500	1,000	1,600
Number of full strokes per mim	52 to 210	40 to 163	—	—	—	—
Range of cutting stroke speeds of ram, m per min	—	—	5 to 36	5 to 34	4 to 30	6 to 30
Table diameter, mm	240	500	630	800	1,250	1,600
Maximum travel of table:						
Longitudinal travel, mm	350	500	650	800	1,250	1,600
Cross travel, mm	280	400	—	650	1,000	1,250
Rotary travel, deg	360	360	360	—	360	360
Range of feeds per full stroke:						
Longitudinal feed, mm	0.1 to 1	0.1 to 1.2	0 to 2.5	0 to 2.5	0.2 to 7	0.2 to 12.8
Cross feed, mm	0.1 to 1	0.1 to 1.2	0 to 2.5	0 to 2.5	0.2 to 7	0.2 to 12.8
Rotary feed, deg	0.07 to 0.67	0.064 to 0.81	0 to 1.45	—	0.75 to 26.25 mm	0.2 to 12.8 mm
Power of main drive motor, kW	0.8/1/ /1.4/1.5	3	7	10	28	43
Net weight, kg approx.	1,200	2,000	5,100	7,000	18,500	45,500

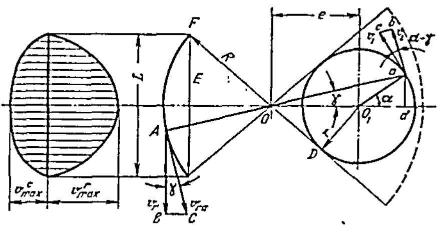


Fig. 200. Ram velocity diagram of a slotter

through bevel gears $18T$. Rotation of screw $XVII$ moves the crankpin along the guides of the bull gear and thus changes the length of the ram stroke.

The feed motion is transmitted from the bull gear through spur gear $50T$, two pairs of bevel gears and the telescopic shaft to shaft IV on which ten different eccentric cams are keyed, thereby enabling ten different feeds to be obtained.

The roller of lever *6* is shifted in line with the required cam from which it receives an oscillating motion. This motion is transmitted to segment gear $68T$. Through gear $34T$, the segment gear transmits reciprocating motion to a lever carrying pawl *7* of ratchet wheel $48T$. From this ratchet wheel, motion is transmitted through the bevel gear reversing unit to spur gear $40T$ and further, through safety clutch SC to shaft $VIII$ Motion is transmitted from this shaft through the spiral gears $20T$ to shaft IX which drives the cross and rotary feed motions of the table. The table obtains longitudinal feed from screw XV which is driven from another pair of spiral gears $20T$ at the other end of shaft $VIII$.

Cross feed is effected by screw XIV, and rotary feed, by means of worm gearing driven through shafts XI, XII and $XIII$.

Slotters with a hydraulic drive are widely used. The hydraulic circuit of such a slotter is shown in Fig. 201.

The variable-displacement piston pump P_{vd} delivers the working fluid to distributing panel *1* with START-STOP valve V_1 and reversing valve V_2 operated by pilot valve V_3. Valve V_3 is reversed at the extreme positions of the ram by the trip dogs of master switch which is linked by a mechanical transmission to the ram. During the cutting stroke, pump P_{vd} draws the working fluid from the tank through check valve *2* and delivers it into the

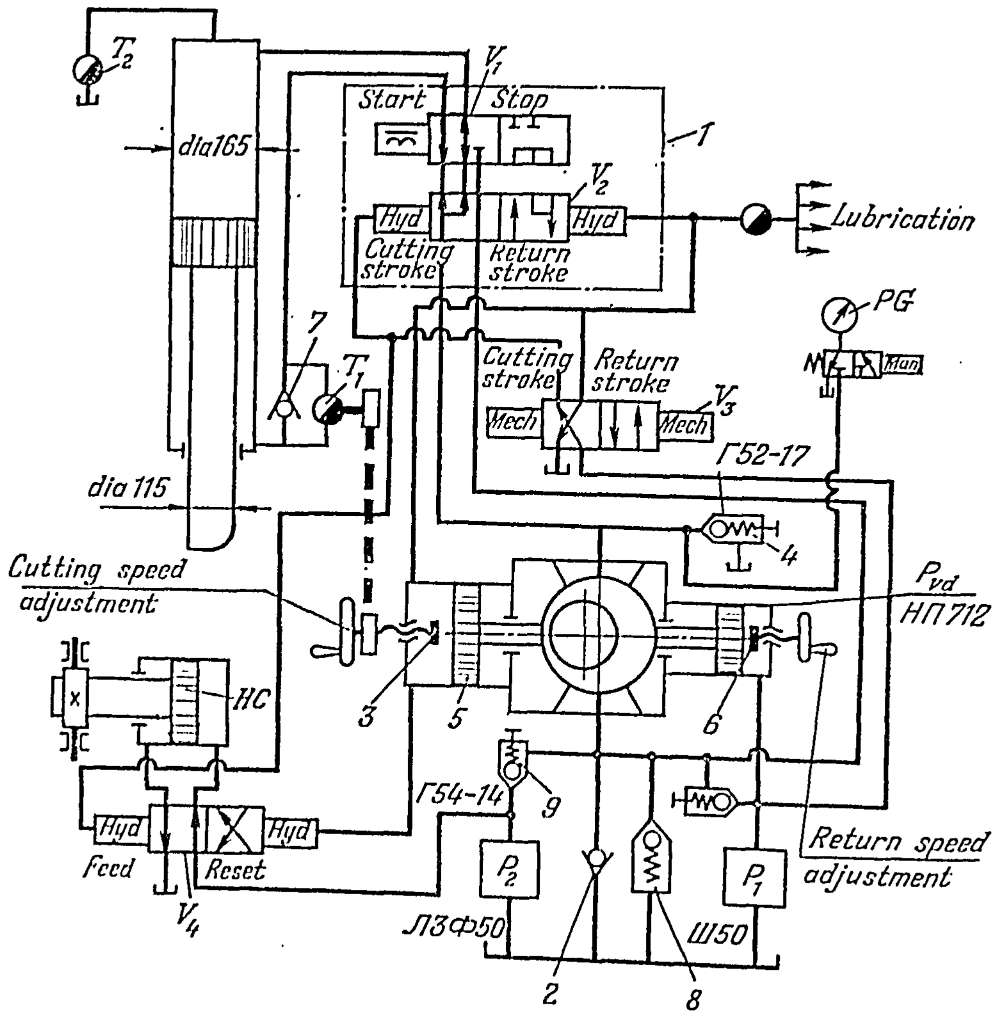


Fig. 201. Hydraulic circuit of a slotter

upper end of the hydraulic cylinder. Fluid from the rod end of the cylinder is forced out through flow-control valve T_1, used to maintain a back-pressure in the rod end of the cylinder. The speed of the cutting stroke of the ram is set by stop *3* which is linked through a mechanical transmission with valve T_1. The circuit is protected against overloads by relief valve *4*. At the lower extreme position of the ram, when pilot valve V_3 is operated by a trip dog, working fluid, delivered by auxiliary low-pressure gear pump P_1, passes to reversing valve V_2 for shifting it to the return stroke position. At the same time, the working fluid is admitted to the left-hand side of piston *5*, thus shifting the slide-block housing to the right to stop *6*

which determines the pump eccentricity and consequently the speed of the return stroke. The working fluid is delivered to the rod end of the cylinder through valve V_2 and check valve *7*, while the working fluid from the upper end of the cylinder is directed by reversing valve V_2 to the suction end of pump P_{rd}. Since the volume of working fluid draining from the upper end of the cylinder is greater than that delivered to the rod end, surplus fluid is drained to the tank through backpressure valve *8*.

Throttle valve T_2 serves to bleed the air from the upper end of the hydraulic cylinder. Table feed is provided for by vane pump P_2 and relief valve *9*. The pump delivers working fluid to the feed cylinder *HC* through valve V_4 controlled by pilot valve V_3.

9-7. Attachments Extending the Processing Capacities of Slotters

1. The teeth of clutches and gears can be cut by the generating method in an ordinary slotter equipped with a special gear-shaping attachment. This attachment (Fig. 202*a*) is secured to the lower part of the ram housing (Fig. 202*b*).

The gear-shaping attachment operates as follows. Housing *1* of a worm reducing gear and bracket *3* with rotating shaft *5* are fastened on plate *2*. Sprocket *4*, keyed on one end of shaft *5*, is connected by roller chain with a sprocket mounted on the table feed drive shaft.

Mounted on the other end of shaft *5* is change gear *6*, linked through the other change gears of the quadrant with a worm (not shown in Fig. 202) and worm wheel *9*. The worm wheel is keyed on a bronze sleeve *8* having a spline hole in which the splines of cutter spindle *7* slide. The upper end of the cutter spindle is fastened to the slotter ram in such a manner that the spindle is free to rotate about its axis.

During operation, the cutter spindle is reciprocated by the slotter ram and is rotated by the feed drive shaft of the table through the chain drive, quadrant change gears and worm gearing. The slotter table on which the gear blank is clamped rotates in co-ordination with the cutter spindle. If the attachment is properly set up, the gear-shaping cutter and the gear blank will rotate together as if they were in mesh.

The gear-shaping attachment can be used for external and internal spur gears. If the straight splines guiding the cutter spindle are replaced by helical guides, such an attachment can be employed for cutting helical gears.

2. Slotters can be used as presses in some cases (for example, for bending operations), as well as for broaching holes. Such operations can be performed after equipping the slotter with suitable attachments or fixtures.

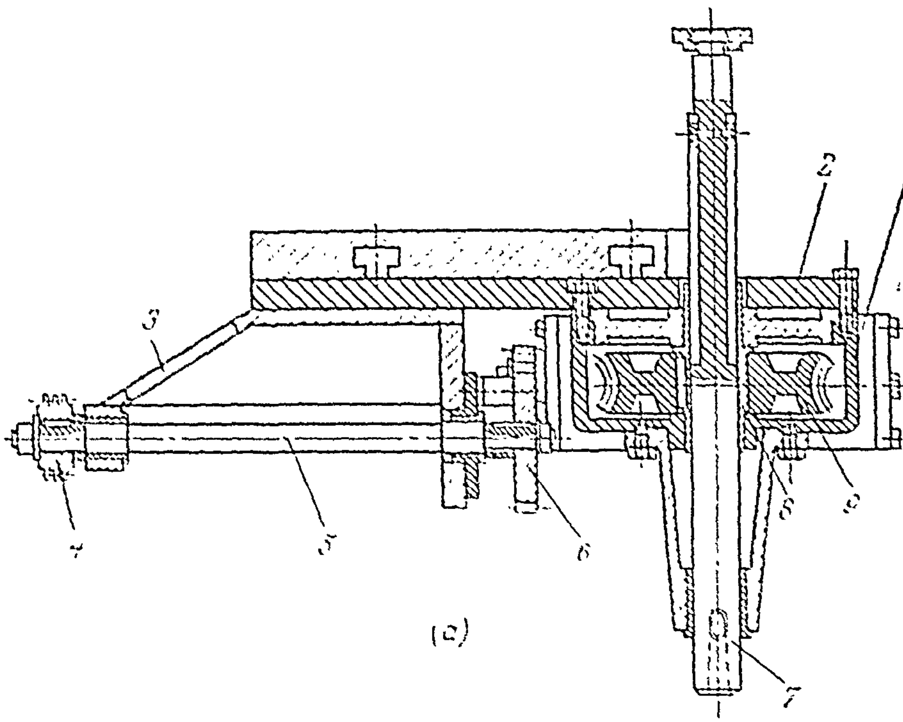
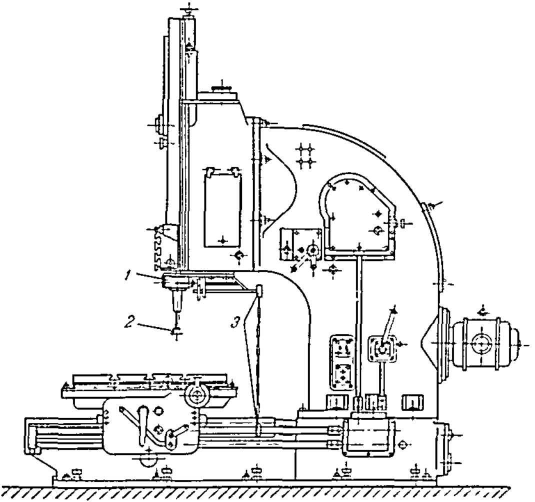


Fig. 202. Cutting internal and external spur gears in a slotter:

(a) gear-shaping attachment: 1—housing; 2—plate; 3—bracket; 4—sprocket; 5—shaft; 6—change gear, 7—cutter spindle; 8—sleeve; 9—worm wheel; (b) slotter equipped with a gear-shaping attachment: 1—attachment; 2—gear-shaping cutter; 3—driving sprockets

9-8. Holding the Tool and the Work in Planers, Shapers and Slotters

The work is held on the tables of planers, shapers and slotters either by standard accessories or by special fixtures. The use of the latter can be justified only if a large number of identical parts are to be machined. Workpieces can be quickly located, or aligned, and reliably clamped on the machine table in a properly designed special fixture. Such fixtures are usually intended for



(b)

clamping one or several workpieces depending upon their size, shape and other features.

In most cases, blanks are held in planers, shapers and slotters by standard accessories which include vises and chucks; stop pins, blocks and strips; angle plates; clamping shoes; strap clamps; support blocks, jacks and V-blocks; C-clamps and pillar bolts; T-slot bolts and studs

Small workpieces are frequently clamped in shapers and slotters by machine vises (plain, swivel or universal type) Round work is usually held in slotters

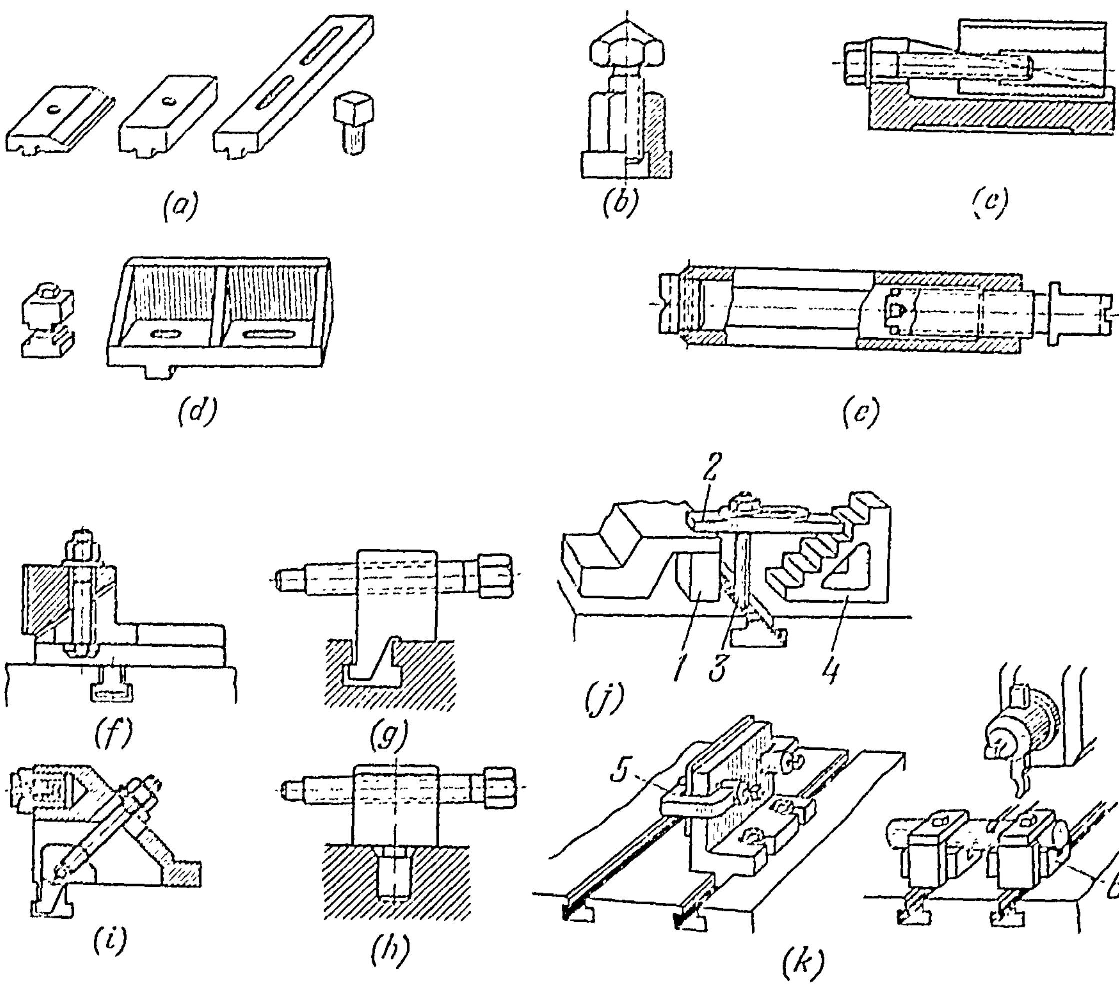


Fig. 203. Work clamping accessories:
(a) stop pins, blocks and strips; (b) screw jack; (c) wedge-type jack; (d) angle plate; (e) pillar bolt; (f) adjustable wedge-type stop; (g) and (h) screw stops; (i) adjustable self-aligning stop; (j) and (k) clamping setups; 1—support block; 2—strap clamp; 3—T-slot bolt; 4—step block; 5—C-clamp; 6—V-block

by three- or four-jaw chucks which are secured to the slotter table with strap clamps.

The accessories shown in Fig. 203 are commonly used to set up, align and clamp work in planers and shapers. Screw jacks (Fig. 203*b*) are used to set up blanks of the housing type which usually have a rough (unmachined) locating surface. Wedge-type jacks (Fig. 203*c*) can be employed in setting up workpieces for finishing operations since adjustments as small as 0.01

CHAPTER 10
BROACHING MACHINES

Broaching machines are designed for machining external and internal surfaces of various contours in mass and large-lot production. These machines are distinguished for their exceptionally high output. They produce surfaces that are highly accurate in shape and size.

Machines employed for internal broaching can make holes of any shape and of a length three or more times the transverse dimension (Fig. 204).

Machines used for external broaching can efficiently produce not only flat surfaces, but other ruled surfaces, including those of complex contours. Examples include the external surfaces of main bearings of engine cylinder blocks, main bearing caps, connecting rods and many other similar parts.

The attainable and economically feasible accuracy and surface finish obtained in broaching are listed in Table 28.

TABLE 28

Broaching	Grade of accuracy		Surface finish class
	limits	mean economically feasible	
Ordinary	2-3	2a	5-7
High-finish	1-2	2	8-10

The application of broaching machines is not limited to large-lot and mass production. Certain models of broaching machines are suitable for small-lot and even piece production conditions. One of these is the machine for broaching keyways in the holes of parts of various shapes and sizes. With only seven sets of interchangeable parts, these machines can broach keyways from 3 to 125 mm wide in holes from 12 to 600 mm in diameter.

In comparison with other types of machine tools, broaching machines are notable for their simple construction and operation. This is due to the fact that the shape of the surface produced in broaching depends upon the shape and arrangement of the cutting edges on the broach.

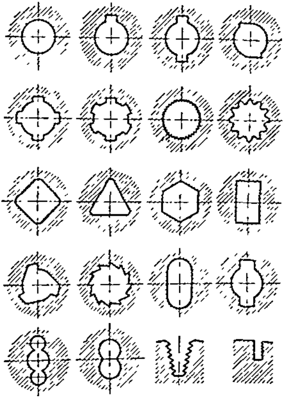


Fig. 204. Typical internally broached shapes

The primary cutting motion in broaching is a straight-line motion of either the broach (Fig. 205), having cutting edges of a shape corresponding to the contour of the required surface, or of the work while the tool is held stationary. Broaching machines have no feed mechanisms since the feed feature is provided for by the gradual increase in height of the broach teeth (each tooth from the roughing to the finishing end is slightly larger than the preceding tooth).

Broaching machines are classified into the principal types as follows: (a) according to their application—as general-purpose and special machines; (b) according to their purpose—as internal and surface broaching machines; (c) according to the direction and nature of the primary cutting motion—as horizontal, vertical and continuous broaching machines; and (d) according to the number of main slides or stations—as single-, double- or multiple-slide machines, and also as single- (ordinary) and multiple-station (indexing table) machines.

TABLE 29

Type	Model	Maximum pulling force, kg	Maximum travel of main slide, m	Range of cutting stroke speeds, m per min	Power of main drive motor, kW	Net weight, kg approx.
Single-slide horizontal broaching machine	7A05	5,000	1	1.5 to 13	10	2,300
	7Б510	10,000	1.25	1.5 to 13	17	3,800
	7Б520	20,000	1.6	1.5 to 11	22	5,800
	7A540	40,000	2	1 to 6.8	40	10,300
	7580	80,000	2	0.5 to 2.8	55	21,000
Single-slide vertical internal broaching machine	763	2,500	0.8	2 to 12	7.5	1,650
	764	5,000	0.8	1.5 to 13.5	10	4,000
	765	10,000	1	1.5 to 13	17	5,300
	766	20,000	1.25	1.5 to 11	22	8,300
	777	40,000	1.6	Up to 5	40	15,800
Vertical surface broaching machine single-slide/dual-slide	773	2,500	0.8	2 to 12	7.5	1,700
	774/774Д	5,000	0.8	1.5 to 11	10	3,400/4,100
	775/775Д	10,000	1	1 to 9/1.5 to 13	17	5,400/8,800
	776/776Д	20,000	1.25	1.5 to 11	22	7,800/19,800
	777	40,000	1.6	2 to 7	40	15,700
Automatic horizontal continuous broaching machine	7581	2,500	—	2.4 to 12	5.5	3,700
	7582	5,000	—	2.4 to 12	10	5,100
	7583	10,000	—	2.4 to 12	22	6,200

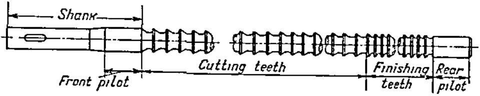


Fig. 205. Internal broach

The principal dimensions specifying the capacity of a broaching machine are the maximum pulling force developed by the slide and its length of stroke. The broaching speed in up-to-date general-purpose machines ranges up to 14 or 15 m per min. Special machines for broaching cylinder blocks, their bearing caps, etc., have much higher speeds that may reach 60 or even 90 m per min. The broaching speed of continuous broaching machines ranges from 1.5 to 15 m per min (Table 29).

Most broaching machines have a hydraulic drive. At present, however, use is being made of an electromechanical drive from d-c motors for high-speed broaching machines.

10-1. Internal Broaching Machines

Both horizontal and vertical machines are available for internal broaching operations (see Table 29).

Figure 206 illustrates a horizontal broaching machine, model 7Б510. It comprises the following principal units: bed *4*, main slide *1*, attached bed *6*, supporting carriage *3*, follower rest *5*, hydraulic drive, main hydraulic cylinder, auxiliary hydraulic cylinder, tank and coolant system *2*.

After the pumping unit (Fig. 207) is switched on, oil is delivered by gear pump P_1 to the chamber of the pressure cylinder *PC* and, at the same time, through pilot valve V_1 and the zero-output, or zero-eccentricity, chamber *4* to the starting valve V_2. Since the area of piston Pn_2 is larger than that of piston P

on the rod of piston

der. This correspond.

ing valve V_3 is in the STOP position, connecting the delivery and suction pipelines, it eliminates small errors in the neutral position setting of the slide-block.

When solenoid Sd_1 of pilot valve V_1 is energized, oil is delivered from pump P_1 additionally to piston Pn_3 and to the right end of starting valve V_3. As a result, the slide-block is shifted to the left to stop *2* which corresponds

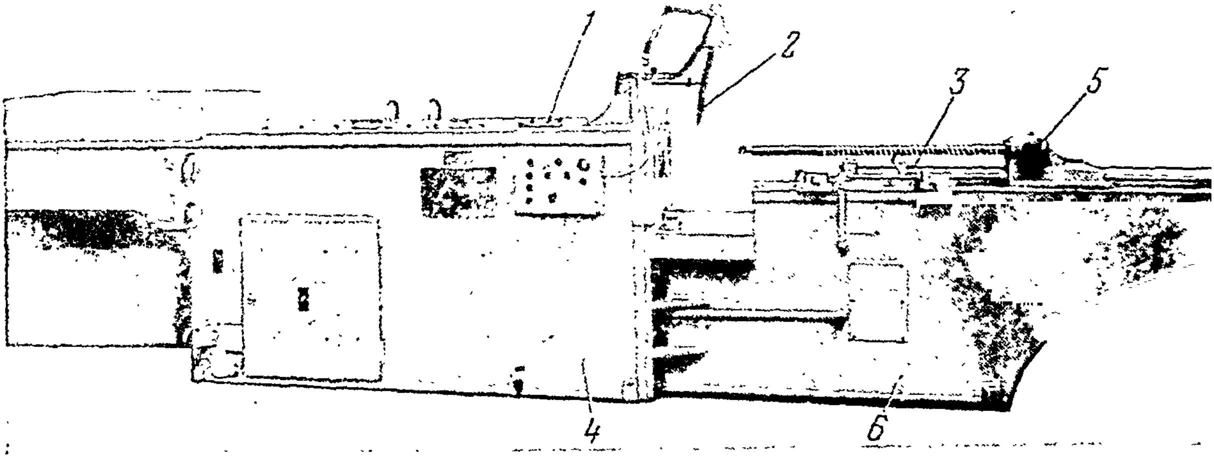


Fig. 206. Horizontal broaching machine, model 7Б510

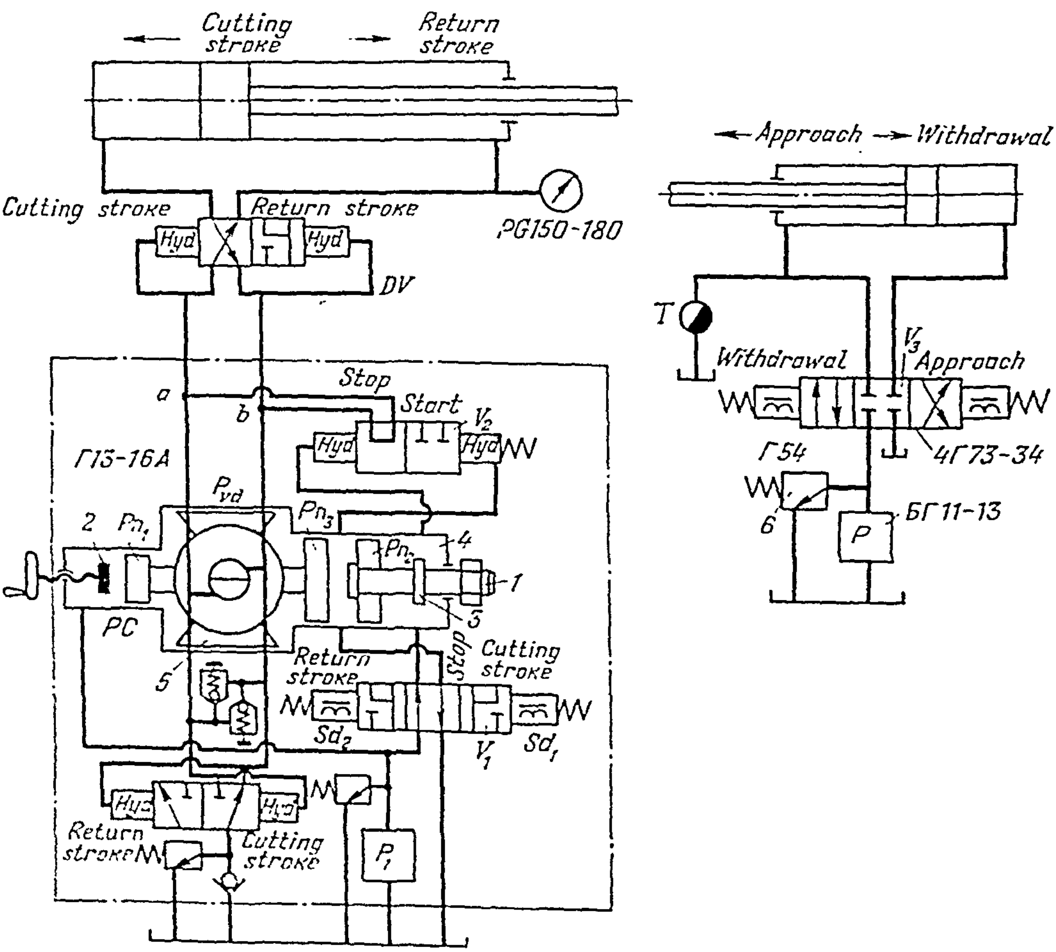


Fig. 207. Hydraulic circuit of the model 7Б510 horizontal broaching machine

to the eccentricity for the cutting stroke. At the same time, a spring shifts the spool of starting valve V_2 to the START position and oil is delivered from the variable-delivery pump P_{vd} along pipeline *a* to the rod end of the main cylinder.

Solenoid Sd_2 of pilot valve V_1 is energized at the end of the cutting stroke. This connects the working chambers of pistons Pn_2 and Pn_3 with the tank. Under the action of pressure piston Pn_1, slide-block *5* is shifted to the right until stop *3* runs up against the housing. This corresponds to the pump eccentricity for the return stroke. Now oil from pump P_{vd} is delivered through pipeline *b* and differential valve *DV* to the head end of the main cylinder. Oil from the rod end is also admitted to the head end. This provides for the rapid return stroke.

The operation of the hydraulic broach-handling drive (for advancing and withdrawing the broach) is co-ordinated with the operation of the main cylinder, and is quite clear from the circuit diagram. In the neutral position of valve V_3 (4Г73-34), oil from pump *P* (БГ11-13) drains to the tank through valve *6* (Г-54). The speed with which the broach is advanced is regulated by flow-control valve *T*.

In the vertical type of internal broaching machine, the broach travels downward through the work and is gripped by the broach puller in the lower part of the main slide (Fig. 208). In addition to the main slide, the machine has a broach-handling slide designed for advancing and withdrawing the broach, and for holding it vertically above the work by means of an automatic broach lifter.

After threading the broach through the starting hole in the workpiece and inserting its pull end into the puller head, the broach-handling slide stops travelling downward. Underneath, the broach is automatically gripped by the puller head, and is pulled through the workpiece when the stroke of the main slide is engaged. The broached workpiece is then removed from the platen. In the return stroke, when the main slide reaches its upper position, the puller head automatically releases the broach. At the same time, the broach lifter of the broach-handling slide automatically grips the retriever on the broach and lifts the broach above the platen to a height permitting a new workpiece to be loaded. The platen of internal broaching machines is more frequently of the stationary type, and the workpiece is not usually clamped, though work-clamping fixtures can be employed whenever necessary.

The broach-handling and main slides are actuated by separate hydraulic cylinders (Fig. 209). The hydraulic drive operates on the same principle as the one considered above (see Fig. 207). A distinctive feature, however, is the provision of the retarding cylinder *RC* for the cutting stroke. It sets the eccentricity of the variable-delivery pump P_{vd} corresponding to the slow cutting stroke speed. The main slide travels at this slower speed at the

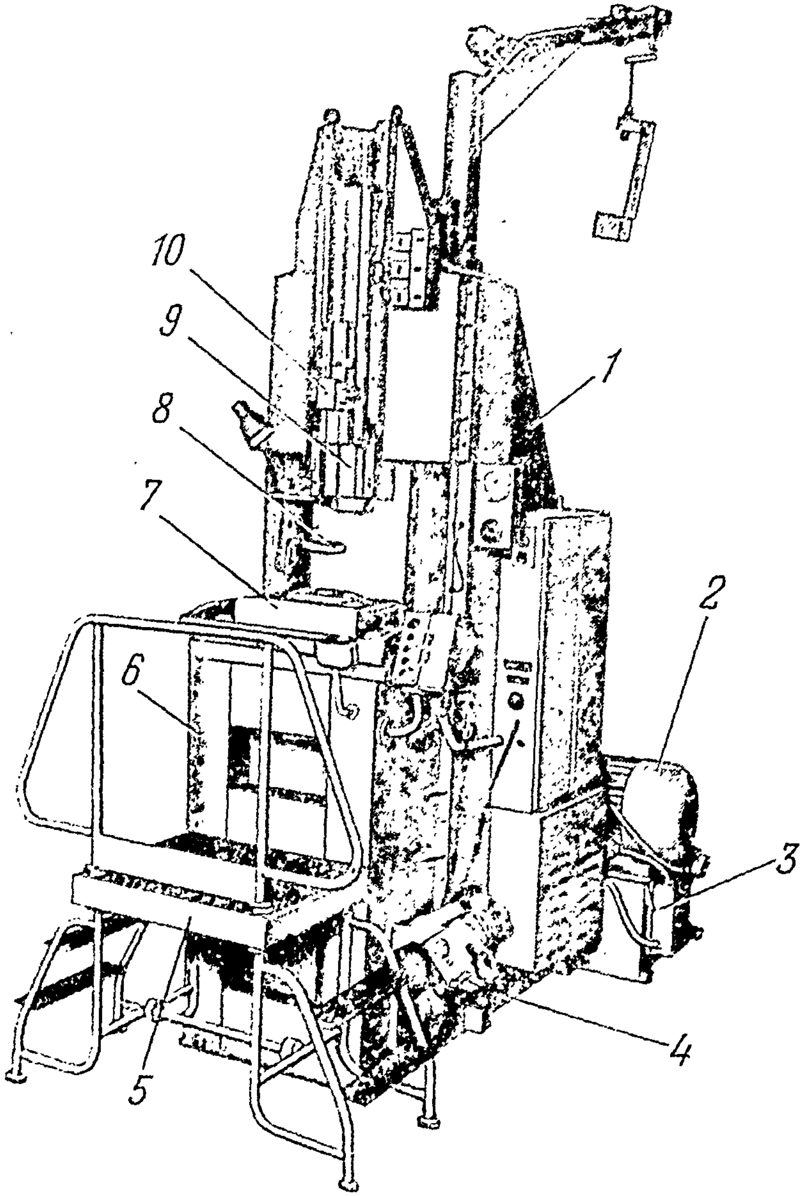


Fig. 208. Vertical internal broaching machine, model 766:
1—column; *2*—drive motor; *3*—hydraulic drive; *4*—base; *5*—platform; *6*—platen base; *7*—platen; *8*—coolant nozzle; *9*—main slide; *10*—broach-handling slide

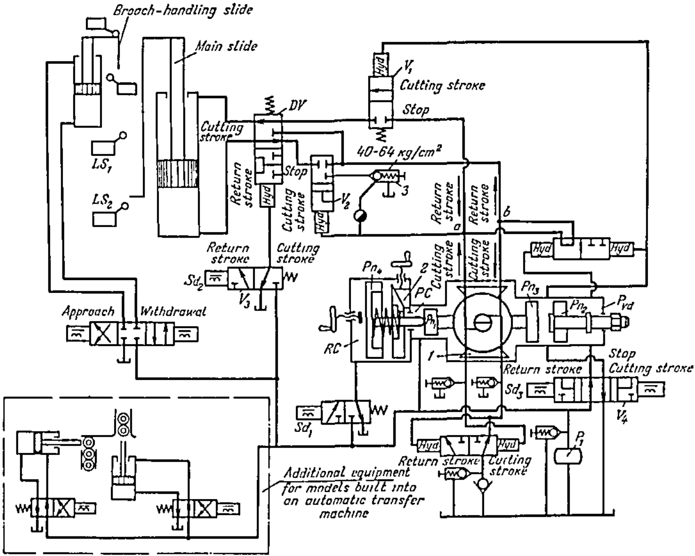


Fig. 209. Hydraulic circuit of a vertical internal broaching machine

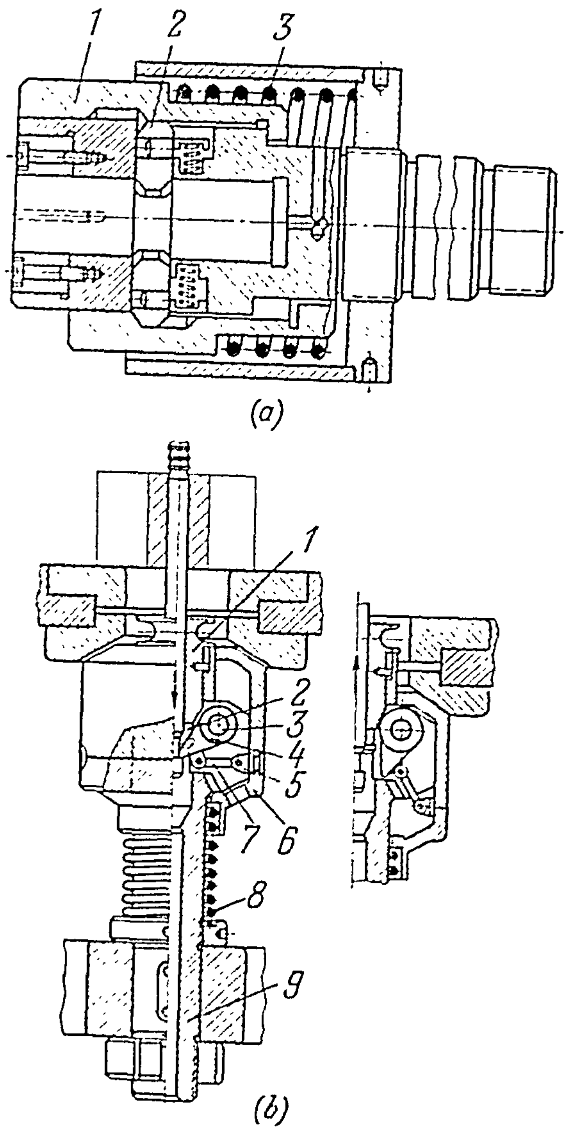


Fig. 210. Puller heads

beginning of the stroke and at the end when the finishing teeth enter the work. When solenoid Sd_1 is energized, oil from pump P_1 is admitted to the retarding cylinder RC. Since the effective area of piston Pn_4 is greater than that of piston Pn_3, slide-block *1* of the variable-delivery pump is shifted to the right until the travel of piston Pn_4 is limited by wedge-type adjustable stop *2*. Solenoid Sd_1 is energized by limit switch LS_1 controlled from the corresponding trip dogs on the slide.

The circuit also includes two pilot-operated valves V_1 and V_2 which connect the ends of the main cylinder with the variable-delivery pump only during the cutting stroke. The surplus oil from the rod end of the cylinder drains to the tank during the cutting stroke through the pilot-operated backpressure valve *3* which maintains a backpressure of 40 to 64 kg per sq cm in the rod end of the cylinder. Differential valve DV, connecting both ends of the main cylinder with channel *b* of the variable-delivery pump during the return stroke, unlike the circuit in Fig. 207, is operated by valve V_3. The spool of valve V_3 is shifted to the return stroke position by solenoid Sd_2 which is energized at the end of the cutting stroke together with solenoid Sd_3 of pilot valve V_4. These solenoids are energized by limit switch LS_2. The broach-handling slide is driven from pump P_1.

Internal broaching machines are available as single-station, as well as two- and multiple-station models. Multiple-station machines commonly

have a rotary indexing table. The broached workpieces are unloaded from the fixtures mounted on the table and the new work is loaded while broaching takes place at an adjacent station, or during the return stroke of the slides.

Broaches are linked to the main slide by means of a puller head. Figure 210*a* illustrates an automatic puller head for gripping the pull end of broaches. The broach pull end is clamped by jaws *2* which are forced by sleeve *1* into the closed position. The sleeve is held by the action of spring *3*. At the end of the return stroke of the main slide, sleeve *1* runs up against the back of the faceplate or a specially provided fixed stop mounted on the faceplate. This slides the sleeve backward to the release or open position in which the broach can be freely removed or inserted.

Another popular type of automatic puller head is shown in Fig. 210*b*. Pawls *4* are pivoted on pins *3* in slots *2* of body *9*. The pawls are linked through hinged tie-rods *7* with brackets *5*. In the extreme upper position, the tapered surface in the platen forces back sleeve *6*, compressing spring *8*, so that tie-rods *7* spread apart the ends of the pawls. Upon downward travel of the main slide, spring *8* is released. Due to its action on sleeve *6* and tie-rods *7*, pawls *4* grip the pull end of the broach. Interchangeable inserts *1* centre the broach in the puller head.

10-2. Surface Broaching Machines

Both vertical and horizontal machines are employed for surface broaching. Surface broaching can also be performed in the continuous-type machines.

Horizontal surface broaching machines have a slide with a long stroke, and broaching is usually performed in both directions. A block diagram of a horizontal broaching machine, manufactured by the Cincinnati Company (USA), is shown in Fig. 211. Workpiece *7*, pushed by loading conveyer *8* along roll table *6*, is loaded into rotary fixture *5* in which the workpiece is clamped and carried to the working zone of upper broach *9*. The main slide travels to the left and broaches the workpiece. Then the workpiece is transferred by turn-over device *4* to fixture *3* in which it is machined by broach *10* when [illegible] this the completely broached workp[illegible] along roll table *2*.

Vertical surface [illegible] ertical models for internal broaching in that the main slide and platen are of different construction and that they have no broach-handling slide (Fig 212).

The work is clamped in a fixture mounted on receding table *1* The broach is clamped by means of the main holder on main slide *2* which travels along the vertical ways of column *3*. The hydraulic circuit of the surface broaching machine (Fig. 213), differing only slightly from the circuits of internal broaching machines (Figs. 207 and 209), incorporates means for preventing

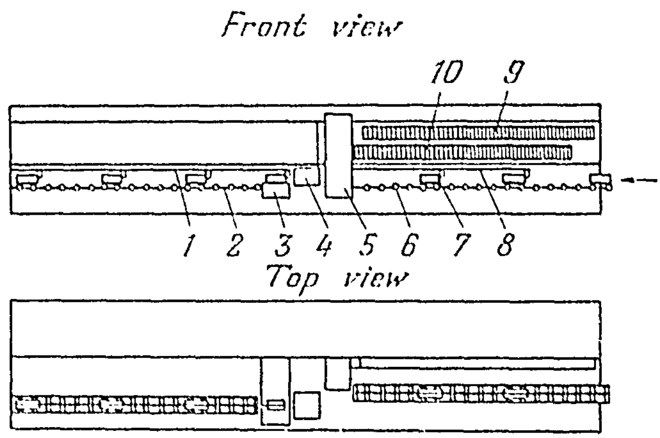


Fig. 211. Block diagram of a horizontal surface broaching machine made by the Cincinnati Company (USA)

the slide stroke from being started before the table is returned to its broaching position. This interlocking feature has been provided for by an arrangement which allows the spool of valve V_2 to be shifted to the cutting stroke position only when the plunger of the table actuating cylinder is in its extreme left position. The main slide can be reversed to the return stroke only when the plunger is in the extreme right position (when the table is in the unloading position) as otherwise differential valve DV cannot be shifted to the return stroke position.

Universal broaching machines, adapted for both internal and surface broaching, are also available. For example, model 7751Y, a vertical machine of this type made in the USSR, has a broach-handling slide that can be switched off and remains in its extreme upper position when the machine is used for surface broaching. The work is clamped in a fixture on a two-station indexing table. The workpiece is loaded and unloaded in co-ordination with the cutting and return strokes of the main slide.

High-production multiple-station broaching machines and continuous broaching machines are employed for surface broaching in mass production. Several broaches may be in operation simultaneously in the multiple-station machines. Thus, for instance, six broaches operate simultaneously in the machine shown in Fig. 214. The workpieces are clamped on a rotary indexing table and advanced in sets to the continuously reciprocating broaches.

Continuous broaching machines are shown schematically in Fig. 215. The horizontal chain-type machine shown in Fig. 215a is designed for the continuous surface broaching of workpieces held in special fixtures mounted on an endless chain. The workpieces are machined by broaches secured

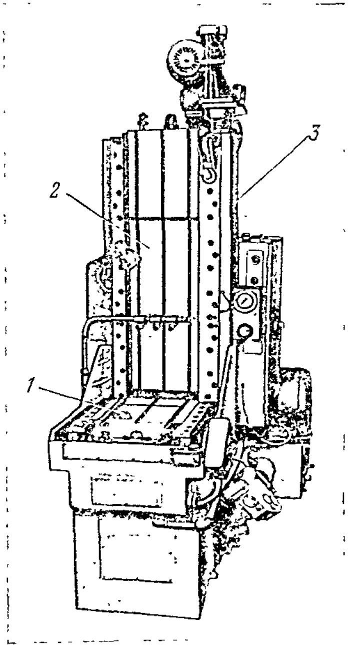


Fig. 212. Vertical surface broaching machine, model 775

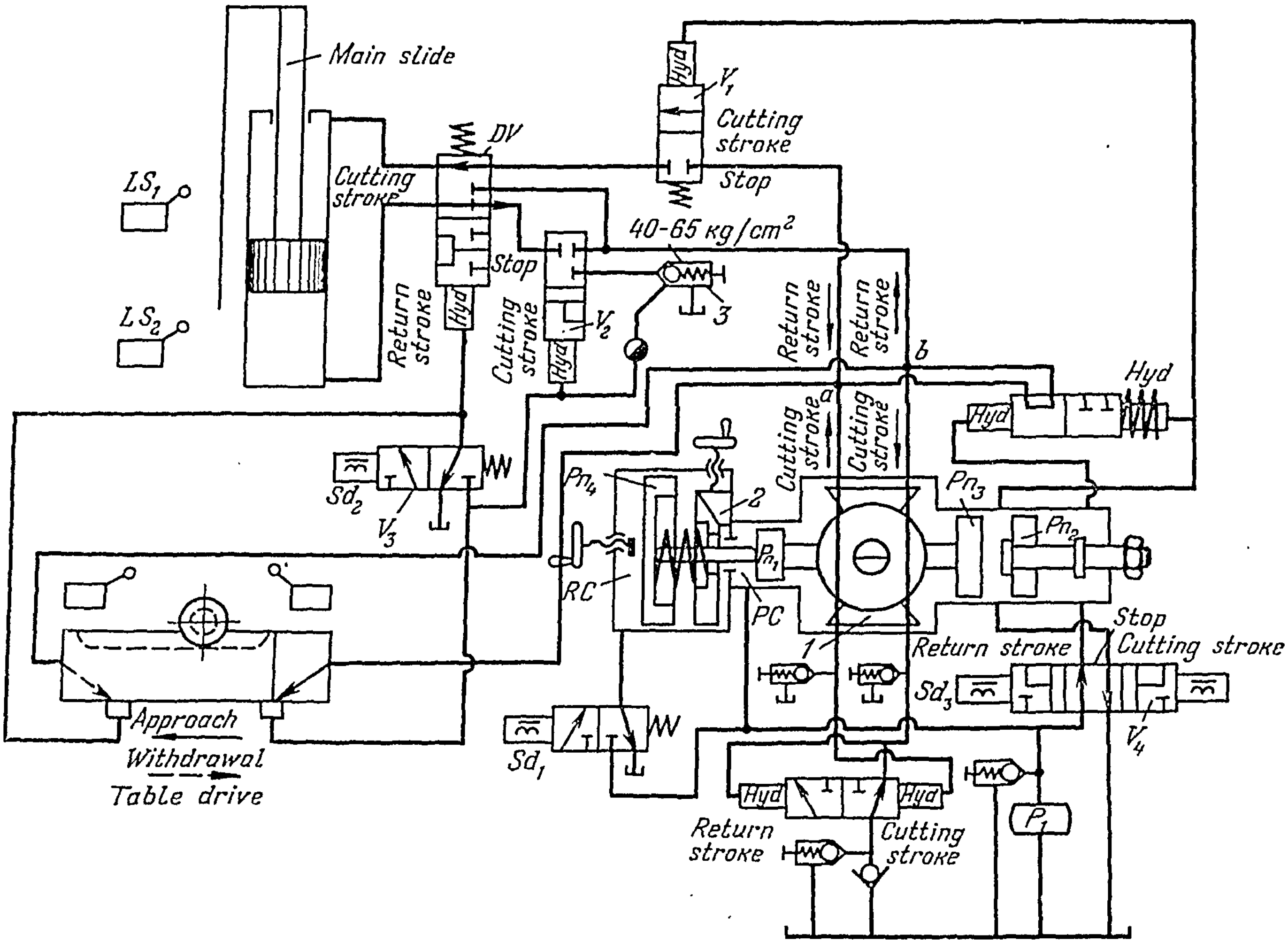


Fig. 213. Hydraulic circuit of a vertical surface broaching machine

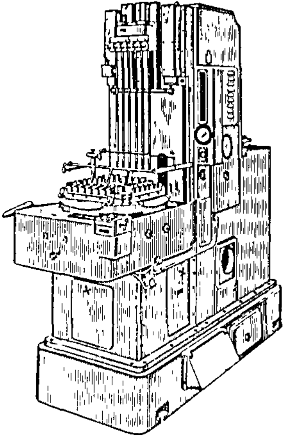


Fig 214 Multiple-station vertical broaching machine

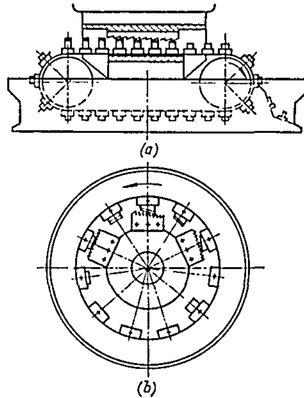


Fig. 215. The principle of continuous broaching machines

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in the upper part of the bed; the broached work is automatically released from the fixtures and falls out into the work chute at the unloading position. In some of the vertical continuous broaching machines the workpieces are machined during their vertical travel.

The rotary broaching machine shown in Fig. 215*b* is intended for continuous broaching of surfaces which are part of a circular cylinder. The broaches can be arranged either in the central part or around the periphery of the rotating table.

On machines of these types the work is clamped, and the broached workpieces are released, automatically.

10-3. Extending the Processing Capacities of Broaching Machines

Not only ruled surfaces, but more complex curvilinear surfaces can be machined in surface broaching machines equipped with a tracer-controlled device. The Oilgear Company (USA) has applied a tracer-controlled device to a vertical broaching machine (Fig. 216). This device enables complex parts, such as turbine blades, to be efficiently broached.

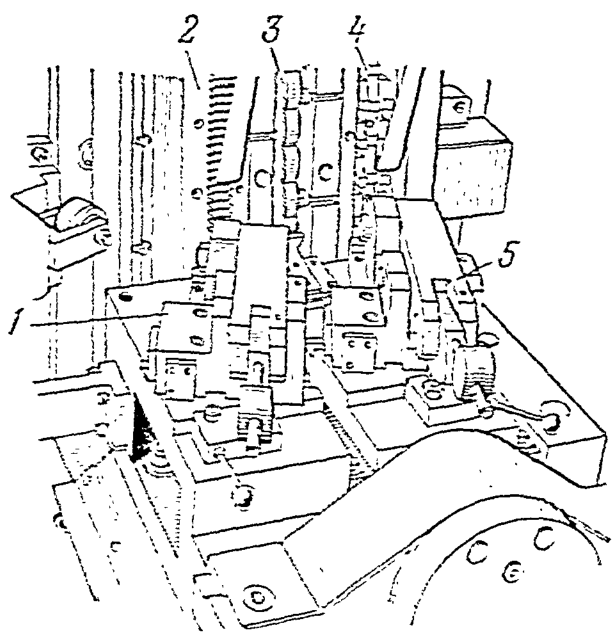


Fig. 216. Tracer-controlled device for a broaching machine:
1 and *5*—clamping fixtures; *2*—roughing broach; *3*—template bar; *4*—finishing broach

Here, two broaches are mounted on the vertical column of the machine. Broach *2* is for roughing and broach *4* for finishing the surface. Arranged between the broaches is template bar *3* on which the curves of the required profile are repeated as many times as there are teeth on the finishing broach. The template bar and the finishing broach operate synchronously.

A two-station fixture is mounted on the receding table. The workpiece is roughed in left-hand fixture *1* and finished in right-hand fixture *5*.

The complex cross-sectional profile of the workpiece is obtained in finish broaching by means of the tracer-controlled device which consists of the template bar and a roller follower. The latter is linked to the right-hand, movable part of the work clamping mechanism and reproduces on the workpiece a profile corresponding to the profile repeated on the template bar. Constant contact of the roller follower with the template bar is ensured by a spring device which is under the pressure of the oil in the hydraulic system. At the beginning of the operation this pressure is about 7 kg per sq cm.

The total force exerted on the template bar during the broaching operation is about 1,250 kg.

10-4. Automation of Broaching Machines

Broaching machine automaticity is being developed along the lines of automatic delivery of the workpieces to the machine, automatic loading and location of the workpieces in the working position and automatic unloading of the broached workpieces, as well as automation of all motions concerned with approach of the tool to the work, its clamping in the broach puller, guidance during the cutting stroke and broach return to the initial position.

At the same time, new designs of machines are being developed both for internal and surface broaching in which the broaching load is axially symmetrical. Research conducted by the Experimental Research Institute for Metal-Cutting Machine Tools in Moscow shows that in machines of this type less than 10 per cent of the developed pulling force is required to overcome the friction forces in the main slide ways instead of 20 or 30 per cent required in ordinary broaching machines. This is due to the fact that there is no moment of couple acting on the main slide in machines with a symmetrical loading system since the pulling force is in strict allignment with the broaching force. As a result, the machining accuracy is considerably higher (two- or threefold).

The construction of the vertical internal broaching machine, model 763, shown in Fig. 217, is based upon a symmetrical system of loading the main slide. This machine weighs 35 per cent less than model 7702B which is of the same capacity but of ordinary design. Moreover, this new machine can

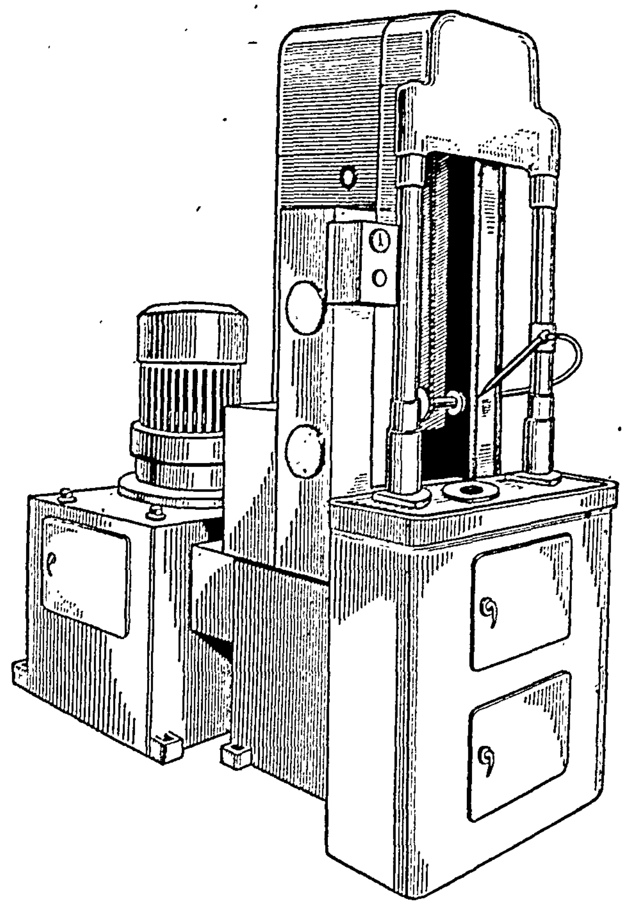


Fig. 217. Vertical broaching machine, model 763

be built into a transfer machine, in which case the workpieces are loaded and unloaded through the column. At the present time, a whole size range of such broaching machines is being designed.

Automatic multiple-station broaching machines are also being developed that perform the same operation on several workpieces, or a sequence of broaching operations on each workpiece. Automatic unit-built machine tools have been designed that perform a number of different machining operations including broaching.

Certain broaching machines are being built into automatic transfer machines and automated production lines. Practically any lot-produced model at the present time can be built into an automated production line. However, since the machining time in broaching is very small in comparison with any other machining process, and in relation to the time required to load

the blank and remove the broached workpiece, a broaching machine will not be efficiently utilized in such a line.

Full utilization of broaching machines is possible in automatic transfer machines comprising only broaching machines. Recently, such transfer machines have found wide application in machining housing-type parts. The broaching speeds in such transfer machines may range from 60 to 90 m per min. Economically, installations of this type are more expedient than transfer machines in which housing-type parts are machined by milling.

CHAPTER 11
GRINDING MACHINES

A distinguishing feature of grinding machines is the rotating abrasive tool. This group of machines is employed chiefly for finish machining operations accomplished by removing layers of metal from the work surface with an accuracy that may reach tenths of a micron, and producing a very high class of surface finish.

Grinding machines handle workpieces that have been previously machined, in most cases, in other types of machine tools, leaving a small grinding allowance whose magnitude depends upon the required class of accuracy, size of the work and the preceding machining operations to which it has been subjected.

Improvements made in recent years in the quality of grinding wheels and machines, and the latest developments of up-to-date blank manufacture (rolling, drop forging, investment and other precision casting processes, etc.) enable high-production grinders to be used in many cases for rough and finish grinding instead of lathes, milling and other machines performing semifinishing operations.

Operations efficiently performed by grinding machines include: (a) roughing and cutting off blanks; (b) precise machining of flat surfaces, surfaces of revolution, profiles of gear teeth, thread and other helical surfaces, contoured surfaces, etc.; and (c) sharpening all types of cutting tools.

Grinding machines find application in all branches of the engineering industries. The number of types and sizes of general- and single-purpose grinding machines in operation in the USSR is over 30 per cent of the total number of types and sizes of metal-cutting machine tools in Soviet plants. A large share of these are single-purpose grinders.

In accordance with the shape of the ground surface and the kind of grinding they do, general-purpose grinding machines can be classified into the following main types: cylindrical, internal, surface and centreless grinding machines.

The accuracy of surfaces machined in grinders depends upon the type of operation being performed (cylindrical grinding, internal grinding, etc.)

TABLE 30

Grinding	Grade of accuracy	
	limits	mean economically feasible
Roughing	3-4	3a
Finishing	1-2a	2
Precision	1	1

and the grinding speeds and feeds. General grinding accuracy data are listed in Table 30.

Attainable classes of surface finish are indicated below for each type of grinding machine.

11-1. Cylindrical Grinding Machines

Cylindrical grinding machines are intended for grinding external cylindrical and tapered surfaces, and are further subdivided into the universal and plain types.

In addition to the small table swivel (up to $\pm 6°$), universal cylindrical grinders also provide for swivelling the workpiece and the grinding wheel by swivelling headstock *3* (Fig. 218) and wheelhead *4* about their vertical axes through a large angle. This enables steep tapers and end faces to be ground in these machines. Universal grinders are usually equipped with an additional head or attachment for grinding holes.

In a plain cylindrical grinder only the work table can be swivelled through an angle of $\pm 6°$. This is used for grinding tapers with a small included angle.

The capacity of a cylindrical grinder is specified by the maximum diameter and length of workpiece that can be accommodated. In the general-purpose grinders manufactured in the Soviet Union, the maximum workpiece diameter ranges from 100 to 800 mm, and the maximum length from 150 to 6,000 mm (Table 31).

Up-to-date cylindrical grinding machines operate on a semiautomatic or automatic cycle and can be efficiently employed for mass, lot and piece production. Many models have provision for installing an automatic in-process size control device. The roughness values of surfaces ground in *cylindrical grinders should be within the values stipulated for the 4th and* 5th classes after rough grinding, 7th and 8th classes after finish grinding

TABLE 31

Cylindrical grinders	Model	Maximum diameter	Maximum length	Work speed range, rpm	Power of wheel drive motor, kW	Net weight, kg approx.
		of workpiece accommodated, mm				
Universal	3A10П	100	150	100 to 800	0.7	450
	3A110	140	200	75 to 750	2.2	1,200
	3Б12	200	500	50 to 600	3	2,600
	3A130	280	700	50 to 400	3	3,500
	3131	280	1,400	50 to 400	3	5,000
	3140	400	1,000	40 to 350	7.5	7,000
	3A141	400	2,000	40 to 350	7.5	9,500
	3У153	500	1,400	20 to 180	7.5	9,800
	3142	560	2,000	20 to 180	7.5	11,000
Plain	3B110	100	200	100 to 1,200	1.1	1,600
	3A153У	140	500	75 to 750	5.5	2,300
	3Б151П	200	700	60 to 240	7.5	3,100
	3Б161П	280	1,000	60 to 240	7.5	4,000
	3A164	400	2,000	40 to 140	13	10,000
	3A164Б	400	1,400	40 to 140	13	8,000
	3A164A	400	2,800	40 to 140	13	9,200
	3A172	560	4,000	12 to 120	22	22,000
	3A172Б	560	2,800	12 to 120	22	18,000
	3A174	800	6,000	8 to 80	30	28,000
	3A174Б	800	4,000	8 to 80	30	24,000

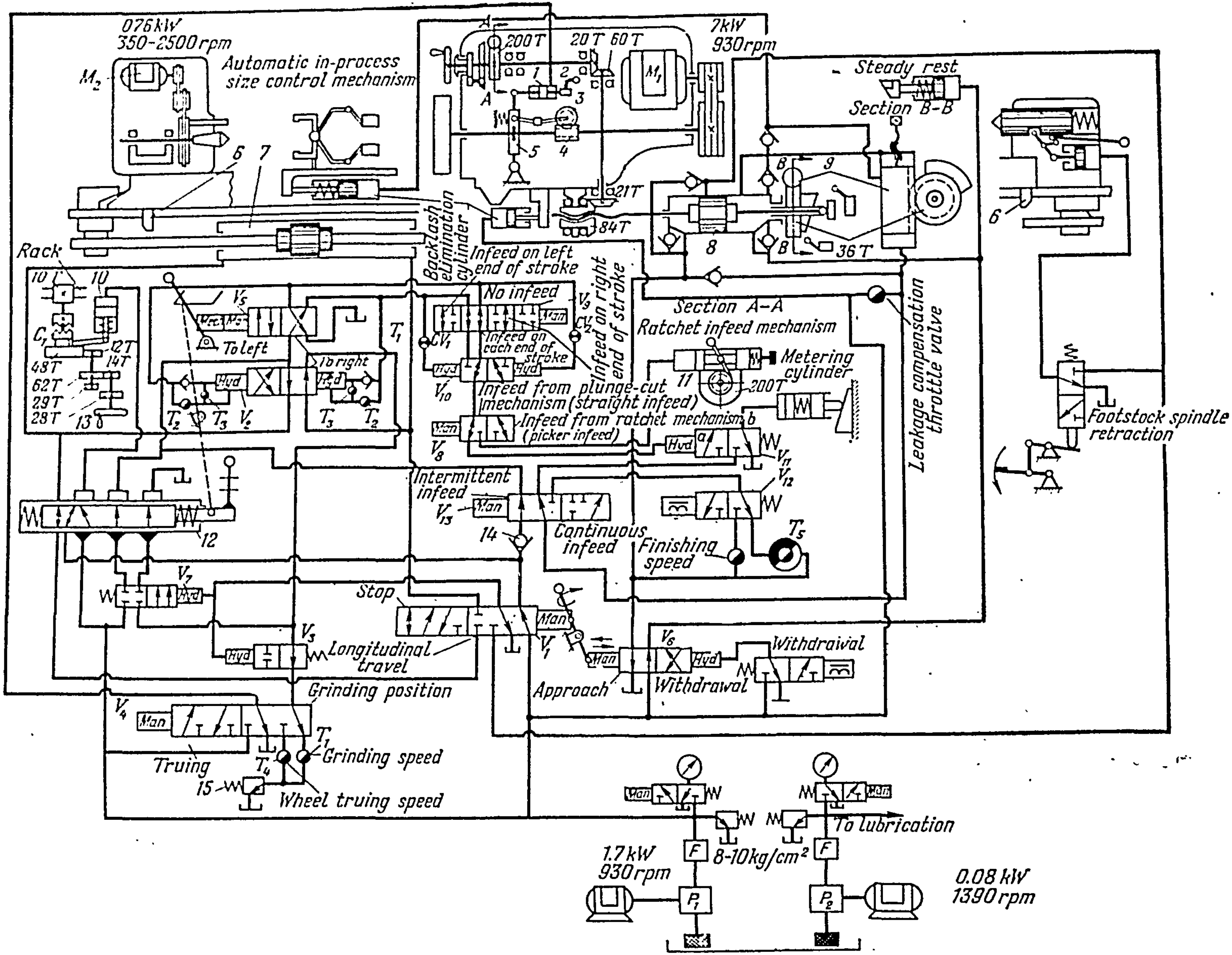


Fig. 219. Combined hydraulic circuit and gearing diagram of the models 3A151 and 3A161 cylindrical grinders

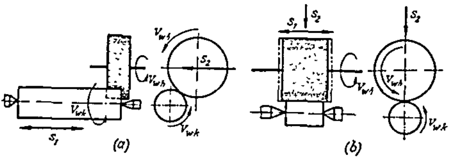


Fig. 220. Diagrams of cylindrical grinding:
(a) traverse grinding, (b) plunge-cut grinding (v_{wk}—work speed, s_1—rate of traverse; s_2—infeed, v_{wh}—wheel speed)

The grinding wheel is powered by motor M_1 (7 kW, 930 rpm) through a V-belt drive with change pulleys. To obtain a better finish on surfaces ground by the plunge-cut method, an axial oscillating motion can be imparted to the wheelhead spindle by means of worm *4* (Fig. 219) and helical gear *3* whose shaft mounts an eccentric cam.

The oscillating motion is transmitted from the cam by means of lever *5* to the wheel spindle with a frequency of 40 full strokes (back and forth) per minute and an amplitude ranging from 0 to 3.4 mm. The oscillating motion of the wheel spindle is disengaged either by lever *2* or by hydraulic cylinder *1*.

Motor M_2 (0.76 kW) drives the workpiece at a speed ranging from 63 to 400 rpm through two V-belt arrangements and the faceplate.

The table can be reciprocated either by the hand traverse mechanism (handwheel *13*, spur gears $\frac{14}{62}\left[\text{or } \frac{28}{29}\right] \times \frac{12}{48}$, and rack pinion *10T* meshing with the table rack), or by the hydraulic drive through the piston rods of cylinder *7*.

Hydraulic table traverse is engaged by switching on the pumping station and shifting valve V_1 to the TABLE TRAVERSE position. Oil is delivered by the pumping station through valve V_1, check valve *14*, valve V_3 and the pilot-operated reversing valve V_2 to the left end of the hydraulic cylinder. *At the same time, oil passes from valve V_1 through table traverse* valve *12* to hydraulic cylinder *10* of the mechanism for interlocking hand table traverse. This cylinder disengages jaw clutch C_1.

From the right end of cylinder *7* oil is forced through valves V_2, V_3 and V_4, flow-control valve T_1 and backpressure valve *15*, back to the tank. The speed of table traverse is determined by the setting of valve T_1. The table is automatically reversed by pilot valve V_5 which is operated by adjustable trip dogs *6*. When valve V_5 is reversed, it shifts valve V_2 to the TO LEFT position and oil from valve V_2 is admitted to the right end of

hydraulic cylinder *7*. Throttle valve T_2 serves to regulate table tarry, or dwell, during reversals, while throttle valve T_3 regulates the smoothness with which the table accelerates following reversals.

For convenience in setting up, the table can be traversed to the right and left, with the wheelhead withdrawn and the hydraulic table traverse switched off. In this case, valve V_1 is set to the STOP position and valve V_6 to the WITHDRAWAL position. After wheelhead withdrawal, oil passes from cylinder *8* through valve V_1 to valves V_3 and V_7 which are shifted to their second positions when their springs are compressed by the oil under pressure. This prepares the circuit for connecting the pressure port of valve V_2 to pump P_1, and its draining port to the tank. These connections occur when the handle of valve *12* is inclined in the desired direction of table traverse, and simultaneously oil is admitted into cylinder *10* to disengage the hand table traverse mechanism. The speed of table traverse is determined by the angle to which the lever of valve *12* is inclined. If the lever is released, valve *12* shifts to its neutral position in which both the pressure and draining ports of valve V_2 are closed, the two ends of hydraulic cylinder *7* are connected together through valve V_1 and hydraulic cylinder *10* is connected to the tank.

To true or dress the wheel, valve V_4 is shifted to the TRUING position. At this, hydraulic cylinder *1* disengages the oscillating movement of the wheel spindle and the draining ports of valve V_2 are connected to the tank through flow-control valve T_4.

Automatic intermittent infeed is accomplished in the given machine either from a ratchet mechanism after shifting valve V_8 to the PICKER INFEED position, or from the plunge-cut infeed mechanism after shifting the same valve V_8 to the STRAIGHT INFEED position. To obtain intermittent infeed, valve V_9 is set to one of the following positions: INFEED EACH END, INFEED AT LEFT END or INFEED AT RIGHT END.

When picker infeed is engaged (feed from the ratchet mechanism), upon table reversal, oil from valve V_5 passes through valves V_9, V_{10} and V_8 into hydraulic cylinder *11*. The piston of this cylinder is shifted to the right and the pawl it carries turns ratchet wheel $200T$ a certain number of teeth. Rotation is transmitted further through bevel gears $\frac{20}{60} \times \frac{21}{84}$ to the nut of the feed screw. After the infeed movement has been completed, valve V_{10} is reversed and it connects hydraulic cylinder *11* with the draining port of valve V_5 while the spring of cylinder *11* returns the piston with the pawl to the initial position. The reversal of valve V_{10} is detained by the cushioning valves CV_1 and CV_2.

If straight infeed from the plunge-cut infeed mechanism is engaged, at the moment of table reversal oil from valve V_5 passes through valves V_9, V_{10} and V_8 to valve V_{11}, shifting it to position *a*; this connects the metering

cylinder to the drain end of hydraulic cylinder *9* of the plunge-cut infeed mechanism. Since, *in grinding, the wheelhead is advanced to the work, oil* from hydraulic cylinder *8* can enter the upper end of hydraulic cylinder *9*. In its travel, the combination rack and piston of cylinder *9* rotates gear $36T$ on whose end face is a cam limiting the travel of the piston of hydraulic cylinder *8*. When gear $36T$ is turned, the cam permits the piston of cylinder *8* to move in the direction of the workpiece. The angle of rotation of the gear with the cam is determined by the volume of oil forced from cylinder *9* into the metering cylinder whose volume is set up with a stop.

When the metering cylinder is full, valve V_{10} is operated. This connects the controlling elements of valve V_{11} with the tank. Under the action of a spring, valve V_{11} is shifted back to position *b* and the metering cylinder is connected to the tank, thus being prepared to receive a new portion of oil.

Plunge-cut grinding is performed by setting valve V_{13} to the CONTINUOUS INFEED position. This disengages the longitudinal traverse and the lower end of hydraulic cylinder *9* is connected through valve V_{12} to the flow-control valves for setting the rate of plunge-cut infeed. If the wheel has *not reached the work, the sleeve of flow-control valve T_5 is turned to increase* the rate of working infeed. This reduces the time spent in "grinding air". As soon as the handle of the flow-control valve sleeve is released, it returns to its initial position and the rate of infeed is again determined by the setting of flow-control valve T_5.

11-2. Internal Grinding Machines

Internal grinding machines are intended for grinding cylindrical and tapered holes. The end faces of the workpiece are usually ground in these machines as well. Surface finish attainable in an internal grinder is within the roughness values stipulated for the 6th and 7th classes after rough grinding, and the 7th and 8th classes after finish grinding

The principal dimension specifying the capacity of an internal grinder is the maximum diameter of hole ground (Table 32). As to the arrangement of their spindle, *internal grinders are classified as horizontal and vertical;* depending on whether the work rotates or remains stationary, internal grinders are classified as ordinary, or chucking, and planetary machines

In addition to the primary cutting motion—grinding wheel rotation—internal grinders of the chucking type have the following working motions (Fig. 221):

(a) work rotation v_{wk};

(b) traverse motion s_1, the reciprocating motion of the work or grinding wheel;

(c) infeed s_2, the periodic crosswise motion of the wheelhead.

TABLE 32

Internal grinders	Model	Maximum diameter ×length of hole ground, mm	Range of wheel speeds, rpm	Range of work speeds, rpm	Available power, kW	Net weight, kg approx.
Universal	3B225	25×50	2,400 to 96,000	250 to 2,500	1.7	2,000
	3B226	50×80	1,500 to 25,000	250 to 1,700	1.7	2,300
	3Б227	100×125	8,600 to 18,000	180 to 1,200	3	2,700
	3A228П	200×200	4,500 to 15,000	85 to 600	5.5	4,000
	3A229	400×320	3,300 to 7,000	40 to 250	7.5	5,500
	3A230	800×500	1,900 to 4,460	10 to 100	17	14,000
Semiautomatic with automatic gauging facilities	3A225Б	16×30	96,000	600 to 2,400	0.8	1,800
	3A226Б	32×50	18,000 to 48,000	650 to 1,600	2.2	2,000
	3A227Б	65×80	13,000 to 24,000	500 to 1,000	4	2,300
	3A228Б	125	7,550 to 13,100	100 to 700	5.5	4,500
Semiautomatic	3A229Б	250	3,300 to 7,000	70 to 400	7.5	5,000
	3A230Б	500	1,900 to 4,460	20 to 250	13	13,500
Automatic with automatic gauging facilities	3A226A	32×50	18,000 to 48,000	650 to 1,600	2.2	2,100
Planetary				Speed of external spindle of wheel		
	3285	200×500		60 to 150	5.5	6,000
	3A286	320×800		40 to 100	7.5	10,000
	3A287	500××1,250		15 to 60	10	15,000
	3288	800××2,000		8 to 40	13	20,000

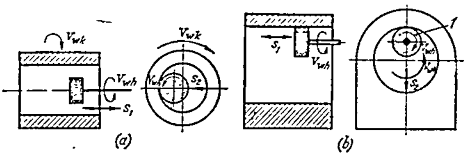


Fig. 221. Diagrams of internal grinding:
(a) in chucking grinders, (b) in planetary grinders

In the planetary-type internal grinders, designed for finishing holes in workpieces of irregular shape, or large heavy workpieces, work rotation is replaced by rotation of the axis of grinding wheel *1* in a circle about the axis of the hole being ground (v_{wk} in Fig. 221*b*). The traverse motion s_1 is obtained by reciprocation of either the grinding wheel or the work table on which the work is clamped. Infeed s_2 is effected by a periodic radial movement of the grinding wheel axis in such a manner that after each full stroke (back and forth), the radius of the circle, described by the wheel spindle about the axis of the hole being ground, increases.

The following mechanisms are found in both chucking and planetary machines: wheel drive, work rotation or planetary motion drive; traverse mechanism and infeed mechanism.

Grinding wheel drive. Internal grinding spindles operate at high and super-high speeds which may reach 150,000 rpm. As a rule, the smaller the wheel diameter the higher the speed should be.

In internal grinders the grinding wheel is driven by one of the following methods.

1. The grinding wheel may be powered from an a-c motor through a flat-belt drive and, in some cases, on the medium and large machines, through a V-belt drive. Canvas belts are suitable for grinding spindle speeds up to 18,000 or 22,000 rpm; further increases in speed being limited by the strength of the belt and its increasing vibrations. Canvas belts operate satisfactorily at surface speeds below 30 m per sec. Silk belts are sometimes used at speeds up to 45 or 50 m per sec. Strong and flexible belts of nylon, suitable for speeds up to 50 m per sec, have become available recently. Combination belts of plastics (polyamides) and chrome-tanned leather permit operation at speeds up to 65 m per sec. Combination belts of perlon and soft chrome-tanned leather can operate efficiently at even higher speeds. Perlon imparts high mechanical properties to the belt while the chrome-tanned leather

increases the coefficient of friction of the belt on the pulleys. Such belts operate successfully at speeds up to 100 m per sec.

2. The grinding wheel may be powered by a pneumatic drive (rotary air motor) enabling wheel speeds up to 80,000 rpm to be obtained. One disadvantage of a pneumatic drive, however, is its lack of a sufficiently flat speed characteristic. In many cases, this does not allow a surface with a sufficiently high class of finish to be obtained. Moreover, the operation of a pneumatic drive is accompanied by a typical unpleasant noise. Because of these drawbacks, pneumatic drives have found only limited application in internal grinders, notwithstanding the fact that they provide stepless wheel speed variation and excellent wheelhead cooling facilities.

3. Electrical grinding spindles with built-in high-frequency motors, aligned with the wheel spindle, have been widely employed in recent years (Fig. 222). The motors may be designed for running at 12,000, 18,000, 24,000, 36,000, 48,000 and up to 144,000 rpm. The smooth operation of these spindles and the high speeds enable surfaces to be ground to a high class of finish and with high precision. Certain difficulties are encountered in varying the grinding spindle speeds.

4. Hydraulic drives can also be used for powering the wheel in internal grinders. A screw-type hydraulic motor *1* (Fig. 223) can be used for this purpose. It is assembled into an integral unit with grinding spindle *2*. This is a very compact arrangement in both the radial and axial directions, has a flat speed characteristic, can operate at high speeds (up to 30,000 or 35,000 rpm), is silent in operation, and enables spindle speeds to be varied very simply.

Angular-contact ball bearings of the precision classes with mist lubrication are employed in the first three types of drives. Aerodynamic and hydrodynamic bearings have also found application in internal grinding spindles in recent years.

Spindle bearings with air-film lubrication (Fig. 222) permit peripheral speeds on the shaft journals up to 100 m per sec with a load up to 5 kg per sq cm over the projected area of the bearing. The absence of mechanical friction between the shaft journal and the bearing liner (they are separated by a layer of air) practically excludes all wear. Clean air is delivered to bearings *1* through passages *2*, *3*, *4* and *5*. The increased air pressure in the lubricating clearance protects the bearings against the entrance of abrasive dust, metal dust and coolant. Air for cooling the electric motor is delivered through hole *6*.

Work rotation or planetary motion mechanism. As mentioned above, one of the working motions in ordinary internal grinders is work rotation whose speed can be varied either in steps or steplessly. Stepped speed variation is accomplished either through a belt drive with stepped pulleys from a single-speed motor, or from a multiple-speed drive in conjunction with a stepped

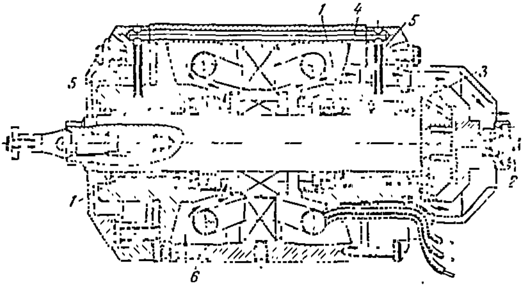


Fig. 222. Electrical grinding spindle with air-film lubrication

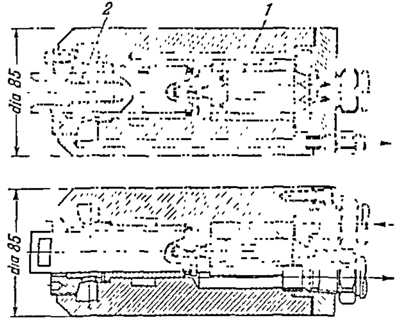


Fig. 223. Grinding spindle, model ГВШ-9, with a screw-type hydraulic motor, designed by the Tractor and Agricultural Machinery Research Institute

pulley V-belt drive, or through a gearbox with a belt drive as the last link of the kinematic chain.

In stepless speed variation, either a variable-speed drive is used, or a d-c electric drive with infinitely variable motor speeds, or a hydraulic rotary drive with stepless speed variation.

Many internal grinders have devices for braking the work spindle.

In the planetary-type grinder, work rotation has been replaced by the planetary motion of the grinding wheel (Fig. 224*a*). Upon the rotation of outer spindle *1*, the axis of wheel spindle *2*, arranged eccentrically in respect to the axis of the outer spindle, describes a circle. The axis of outer spindle *1* coincides with that of the hole being ground, and the required radius of the planetary motion is adjusted by turning an inner eccentric sleeve *3*.

Traverse mechanism. The traverse motion in an internal grinder is accomplished by reciprocation of either the wheel head or the headstock. In most cases, a hydraulic drive of the type employed in surface grinders (see Sec. 11-3) is made use of for this purpose. A crank mechanism of the shaper type is also used, though much less frequently.

Infeed mechanism. All internal grinding machines have automatic infeed mechanisms which provide either a periodic infeed or a continuous infeed, with a constant or variable rate of infeed within a single cycle.

In the great majority of grinders, periodic infeed is effected by a pawl and ratchet wheel mechanism actuated by adjustable trip dogs.

Continuous infeed mechanisms have either electromechanical or hydromechanical drives. In the chucking internal grinders, the infeed mechanism transmits motion either to the headstock or to the wheelhead. Both design versions have found equally wide application.

In the planetary internal grinders, infeed is effected by turning inner eccentric sleeve *3* (Fig. 224*b*) in respect to outer eccentric spindle *1*. This increases the radius of the cylindrical surface described by the axis of wheel spindle *2*. The sleeve is turned by ratchet mechanism *4* through worm gearing *5*, differential *6*, gears *7*, *8*, *9*, *12* and *11*, and worm gearing *10* in which the worm wheel is keyed on the eccentric sleeve.

The workpiece is clamped in an internal grinder in a hand- or power-operated three-jaw self-centring chuck.

Work is clamped in automatic and semiautomatic internal grinders in diaphragm or collet chucks, or other clamping facilities operated either pneumatically or hydraulically. The type and construction of the clamping device depend upon the shape of the workpiece.

Stops and strap clamps are commonly employed to hold the work on the table of planetary-type grinders.

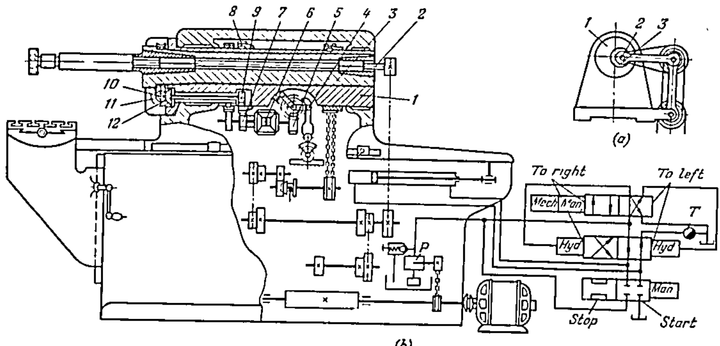


Fig. 224. Combined hydraulic circuit and gearing diagram of a planetary-type internal grinder

11-3. Surface Grinding Machines

The most widely used types of surface grinders at the present time are the following:

1. *Horizontal-spindle reciprocating-table grinders* (Fig. 225). The reciprocation of the rectangular table in these machines is the work table traverse motion (v_{wk}) shown in Fig. 226*a*. The wheelhead has periodic cross feed s_1, equal to the grinding width, after each stroke of the work table. The wheel is fed down to provide the infeed motion s_2 after the whole surface has been ground.

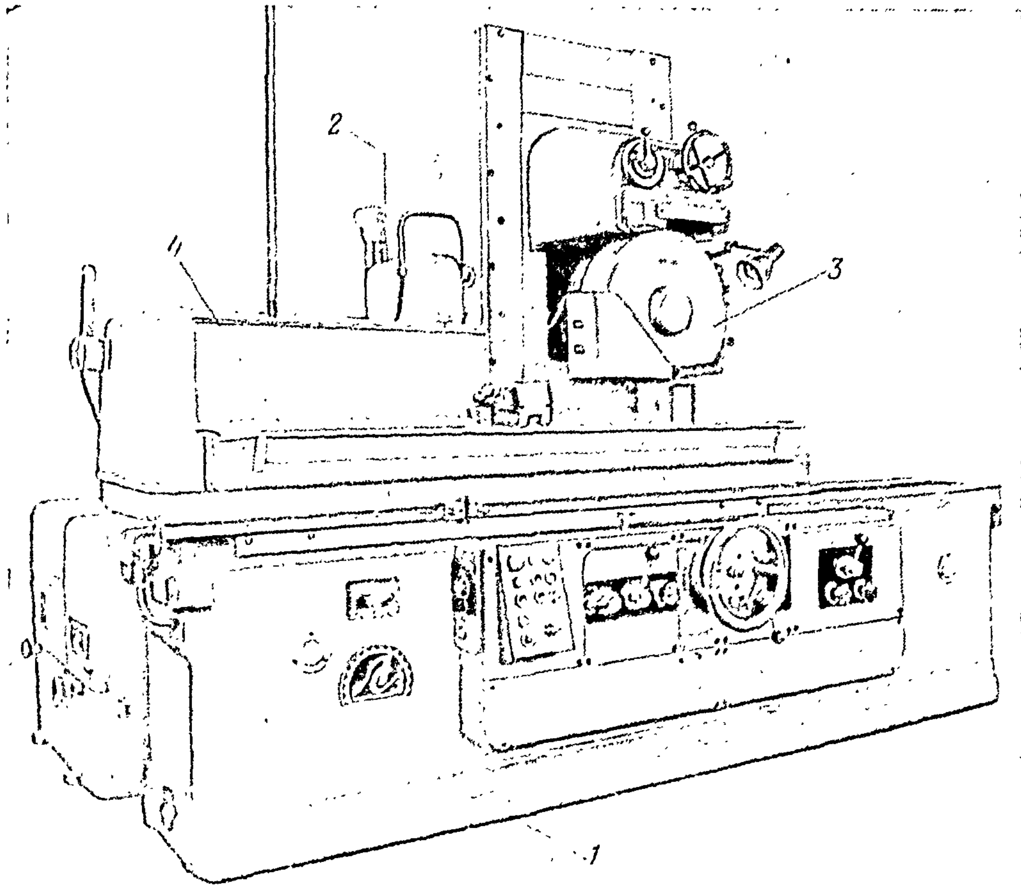


Fig. 225. Horizontal-spindle reciprocating-table surface grinder, model 3Б722: 1—base; 2—column; 3—wheelhead; 4—work table

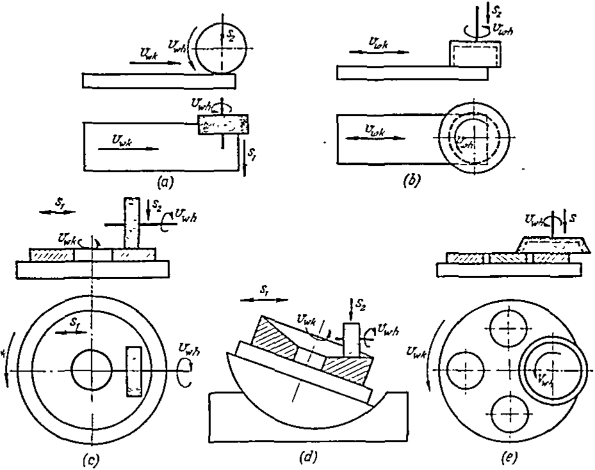


Fig. 226. Motions of the wheel and work in surface grinding

2. *Vertical-spindle reciprocating-table grinders* (Fig. 227). In these machines a cup, ring or segmented wheel grinds the work over its full width, using the end face of the wheel, in one or several strokes of the table (Fig. 226*b*), and is fed down periodically with the infeed motion s_2.

3. *Horizontal-spindle rotary-table grinders* (Fig. 228). The reciprocating cross feed motion s_1 is transmitted in these machines to either the grinding wheel or the table unit (Fig. 226*c*). The work table also rotates with the speed v_{wk}. Vertical travel s_2 of the table or wheelhead is used ... up the grinder.

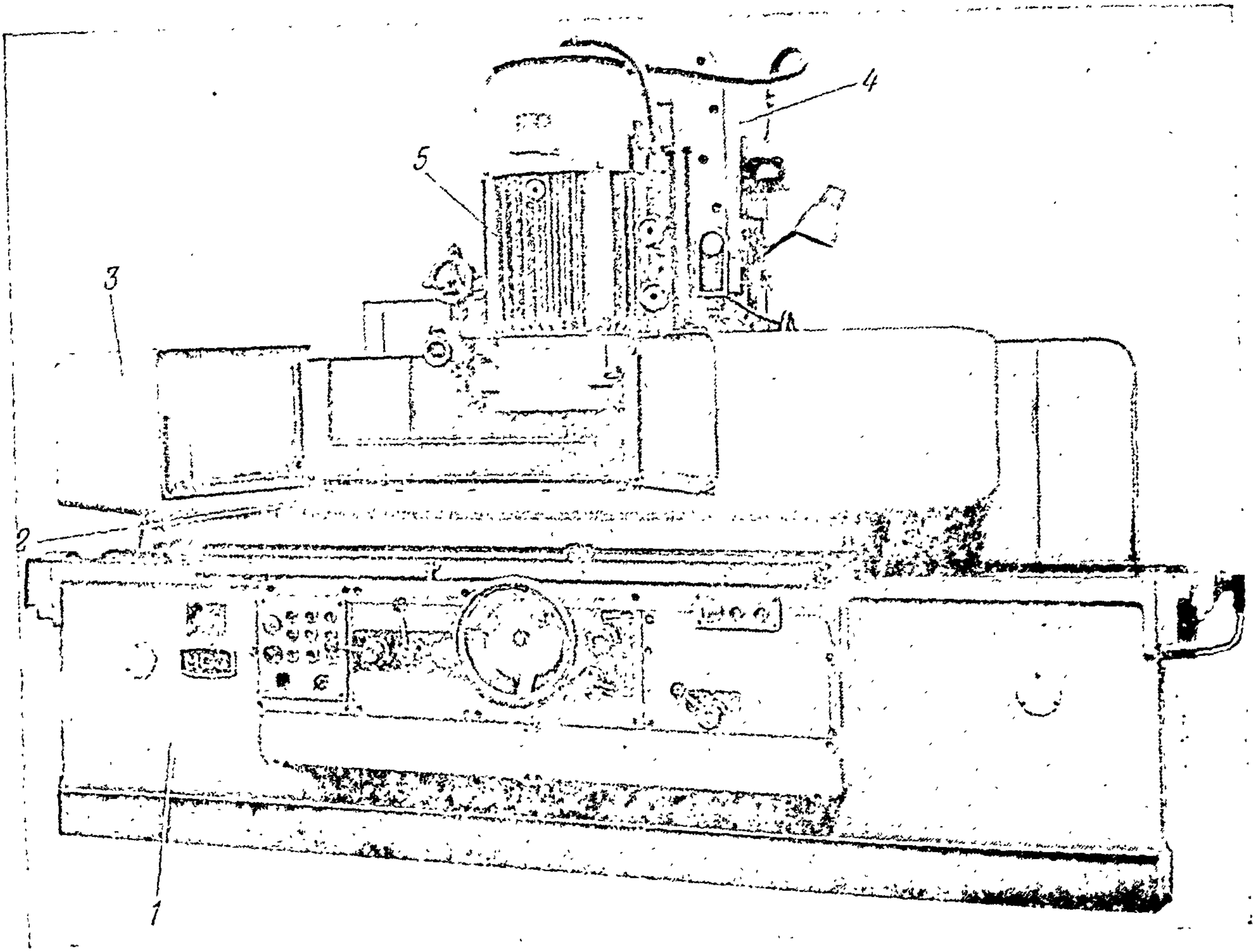


Fig. 227. Vertical-spindle reciprocating-table surface grinder, model 3A732:
1—base; 2—work table; 3—table shield; 4—column; 5—wheelhead

4. *Vertical-spindle rotary-table grinders* (Fig. 229). These machines differ from the vertical-spindle reciprocating-table machines in that the work table is circular and rotates with the speed v_{wk} (Fig. 226*e*).

Surface finish attainable in surface grinders is within the roughness values stipulated for the 5th through 7th classes for rough grinding, the 7th and 8th classes for finish grinding, and the 8th and 9th classes for precision grinding.

The main dimension of surface grinding machines, the size of the work table, is listed in Table 33 for Soviet models being manufactured at the present time. The principal mechanisms of this type of machine are: grinding

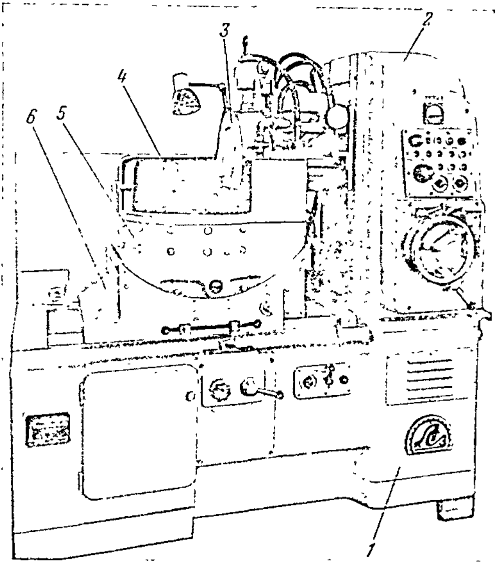


Fig. 228. Horizontal-spindle rotary-table surface grinding machine, model 3Б740:
1—base; 2—column; 3—wheelhead, 4—work table, 5—cradle, 6—saddle

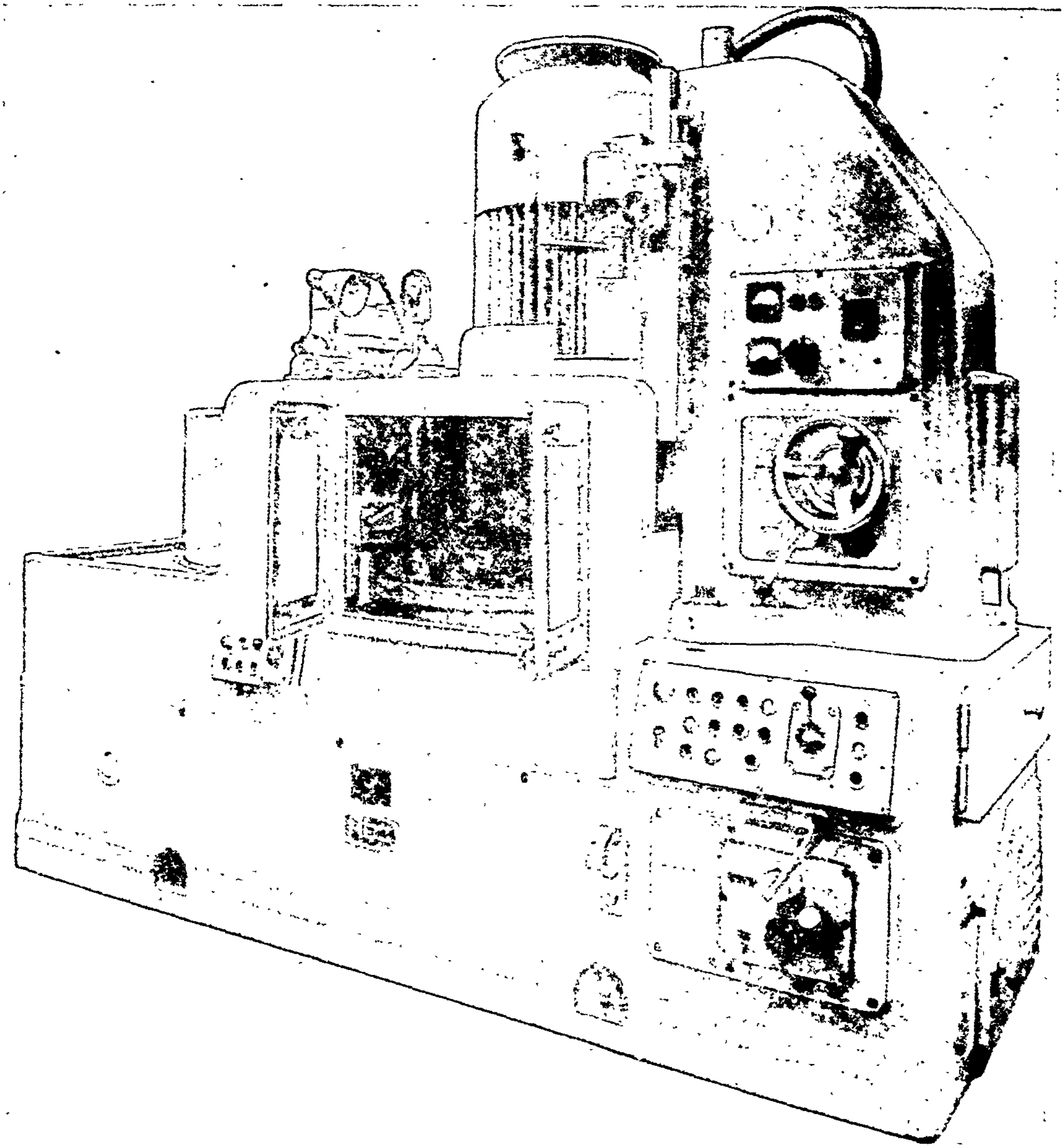


Fig. 229. Vertical-spindle rotary-table surface grinder, model 3Б756

TABLE 33

Surface grinders	Model	Size of table, mm	Work table speed; reciprocation, m/min or rotation, rpm	Available power, kW	Net weight, kg approx.
Horizontal-spindle reciprocating-table	3701	125×400	3 to 25	2.2	2,200
	3711	200×630	3 to 25	2.2	2,900
	3Б721	320×1,000	3 to 25	10	6,700
	3Б724	400×2,000	3 to 30	30	15,700
Vertical-spindle reciprocating-table	3731Б	200×630	3 to 25	4	2,000
	3Б732	320×800	3 to 30	13	6,400
	3733	400×1,500	3 to 30	22	12,000
	3734	630×2,000	3 to 30	30	18,000
Horizontal-spindle rotary-table	3742	dia 200	20 to 200	3	2,150
	3Б740	dia 400	20 to 200	7.5	3,100
	3Б741	dia 800	8 to 80	10	6,000
	375С	dia 1,500	17 to 60	30	32,000
Vertical-spindle rotary-table (table can be moved out from under wheel)	3754	dia 400	6 to 30	22	4,500
	3В756	dia 800	6 to 30	30	6,750
	(КШ-18)	dia 1,600	3 to 18	55	14,300
Production-type with rotating table	3762	dia 1,000	6 to 60	19	25,000
	3763	dia 1,600	4 to 40	19	35,000
	3764	dia 2,500	2 to 20	25	60,000
Double-housing planer-type with horizontal spindles	3508	710×3,200	2 to 25	22	34,000
	3510	900×4,000	2 to 25	22	44,500
	3512	1,120×4,000	2 to 25	22	55,000
Double-housing planer-type with vertical spindles	3508B	710×2,500	2 to 25	30	30,500
	3510B	900×3,500	2 to 25	30	43,000
	3512B	1,120×3,500	2 to 25	30	53,000

wheel drive, traverse mechanism, cross feed mechanism, vertical feed (infeed) mechanism and table drive (for rotary-table models).

The *grinding wheel* in a surface grinder may be driven: (a) by an electric motor built into the wheelhead housing and in line with the wheel (this is the most commonly applied type of drive), (b) by a motor through a belt transmission (used only in the third type of Soviet grinders, as in Fig. 228), and (c) by an electric motor through toothed gearing (not applied in Soviet models).

Traverse mechanisms. In the reciprocating-table machines, the rectangular table is reciprocated along the base ways by a hydraulic drive. Hand table traverse mechanisms are provided only in small and medium-sized models. The hydraulic circuit of such mechanisms is similar to that used in cylindrical grinders (see Fig. 219), except that only one table traverse speed is available.

A traverse motion, effected by travel of the wheelhead, has found application only in certain models of single-purpose grinders. Table traverse speeds with a hydraulic drive range from 20 to 40 m per min.

Rotary-table surface grinders have no traverse mechanisms.

Cross feed mechanisms are found only in horizontal-spindle models. The cross feed motion may be transmitted to:

(a) a movable wheelhead, as in all Soviet reciprocating-table grinders and previously in certain rotary-table models (not produced at present);

(b) a movable table unit as in all rotary-table grinders and in certain reciprocating-table surface grinders (model 3Б70);

(c) a movable column on which the wheelhead is mounted, as employed in certain special surface grinders.

Power cross feed is accomplished hydraulically; hand cross feed—by a screw mechanism.

As a rule, the reciprocating-table machines have both hand and power cross feeds, the latter operating either periodically or continuously.

Periodic cross feed is intended for feeding the wheel across the width of the work in the process of grinding and occurs at each end of the stroke or once per full stroke (back and forth) in the same way as in cylindrical grinders (see Fig. 219). The rate of cross feed can be varied from 1.5 or 3 mm to 0.8 of the width of the wheel per stroke. Continuous feed, in the range from 0.3 to 1.5 mm per min, is used in truing or dressing the wheel and in positioning the wheelhead.

Vertical feed (infeed) mechanism. In all Soviet surface grinders and in most foreign models vertical feed is accomplished by wheelhead motion. In certain small-sized surface grinders, vertical feed is obtained by motion of a knee-type table unit.

The horizontal-spindle reciprocating-table models do not, as a rule, have power vertical feed. This feature is common to all the other surface grinders which also have mechanisms for automatic periodic infeed. In most models

the infeed motions are produced by a ratchet-and-pawl device driven through a lever system by adjustable trip dogs on the table. Hydraulic mechanisms are also used for this purpose.

The rate of periodic infeed in most models ranges from 0.002 or 0.005 to 0.1 or 0.3 mm per table stroke. Most up-to-date models also have mechanisms for rapid vertical traverse of the wheelhead.

Table rotation mechanism. The circular tables of surface grinders are powered by stepped or infinitely variable drives of the following types: (a) from an electric motor through a mechanical gearbox (three or four table rotation speeds); (b) from an electric motor through a variable-displacement hydraulic circuit; (c) from a d-c motor with stepless speed variation. The concluding link of the kinematic chain in all cases is a V-belt drive or worm gearing.

In the horizontal-spindle rotary-table models, the spindle of the work table is mounted in a cradle *5* (Fig 228) and can be tilted 10° from the vertical to either side. This enables convex or concave tapered surfaces to be ground in addition to flat surfaces (see Fig. 226*d*).

11-4. Centreless Grinding Machines

In respect to the kind of surface they can grind, centreless grinders are classified as external and internal centreless grinders. Their principal dimension is the maximum diameter of surface that can be ground (Table 34).

Surface finish attainable in centreless grinding is within the roughness values established for the 5th through 7th classes after rough grinding, 7th and 8th classes after finish grinding, and 8th and 9th classes after precision grinding.

Workpiece *3* (Fig. 230) is supported in an external centreless grinder on work-rest blade *4* and between grinding wheel *1* and regulating wheel *2*. The grinding wheel rotates at a peripheral speed of 30 to 40 m per sec and removes the grinding allowance from the workpiece. The regulating wheel rotates at a peripheral speed of 10 to 50 m per min. It imparts both rotation and axial traverse motion to the workpiece.

In an internal centreless grinder, workpiece *3* (Fig. 231) is rotated between support roll *1*, pressure roll *2* and regulating roll *5*, and is ground by grinding wheel *4*.

The workpiece, arranged between the wheels or rolls and supported by the work-rest blade or rolls, rotates at approximately the same peripheral speed as the regulating wheel or roll, *since the friction between the regulating* wheel and workpiece is substantially greater than between the workpiece and the grinding wheel whose peripheral speed is 75- to 80-fold that of the regulating wheel.

TABLE 34

Centreless grinders	Model	Maximum diameter ground, mm	Speed of regulating wheel or roll, rpm	Available power, kW	Net weight, kg approx.
Semiautomatic for external grinding	3Г180	4	25 to 350 and 450	2.2	1,000
	3Д180	6	25 to 350 and 450	3	1,200
	3M182	25	20 to 150 and 320	7.5	2,200
	3A184	80	10 to 130 and 300	13	5,100
	3M185	160	12 to 100 and 280	22	8,000
	3186	250	15 to 90 and 200	30	14,000
	3A187	320	8 to 70 and 185	55	20,000
Automatic for external grinding	3M182K	25	20 to 170 and 320	7.5	2,500
	3M184K	80	15 to 130 and 300	17	5,500
	3M185K	160	12 to 100 and 280	22	8,500
Automatic for internal grinding	(6C85)	65 to 175	170 to 340	7.5	5,400
	3A229C	250	67 to 500	7.5	5,500
	(Л5463)	50	445 to 1,350	3	2,300
	(6C86)	65 to 175	170 to 340	7.5	5,400
	6C138	120 to 280	188 to 520	7.5	7,800

Three methods of cylindrical centreless grinding exist and are widely employed in practice: through-feed grinding (Fig. 232*a*), infeed grinding (Fig. 232*c*) and end feed grinding (Fig. 232*d*).

The axial traverse motion is imparted to the workpiece by the regulating wheel because the latter is inclined at a certain angle α in respect to the axis of the grinding wheel (Fig. 232*a*) or because the work-rest blade is inclined at an angle α (Fig. 232*b*). In either case, the rate of traverse as indicated on these diagrams depends upon the peripheral speed of the regulating wheel and the sine of α, the angle of inclination of the wheel or blade. Thus, the rate of traverse

$$s = v_2 \sin \alpha \text{ m per min}$$

while the peripheral speed of the workpiece (work speed) is

$$v_{wk} = v_2 \cos \alpha \text{ m per min}$$

where v_2 = peripheral speed of the regulating wheel, m per min
α = angle of inclination of the wheel or blade.

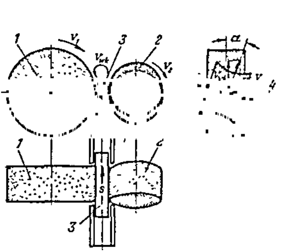


Fig. 230. Motions of the wheel and work in centreless cylindrical grinding:
1—grinding wheel, 2—regulating wheel; 3—workpiece, 4—work-rest blade

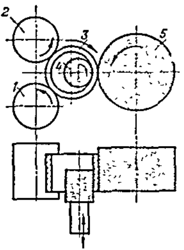


Fig. 231. Motions of the wheel and work in centreless internal grinding:
1—support roll, 2—pressure roll; 3—workpiece; 4—grinding wheel; 5—regulating roll

Suitable values of the angle of inclination are: $\alpha = 1.5°$ to $6°$ for rough grinding, and $\alpha = 0.5°$ to $1.5°$ for finish grinding.

Plain cylindrical workpieces (or stock) and the cylindrical portions of the largest diameter on stepped and contoured workpieces can be ground by the through-feed method. In grinding work of a length many times greater than the width of the wheel, heavy workpieces of large diameter and narrow rings of a height considerably less than their diameter, feeding mechanisms of [illegible] work into the grinding zone. [illegible] ding and regulating wheels [illegible] his purpose, the face of the regulating wheel in the first case or the faces of both regulating and grinding wheels in the second case (with an inclined work-rest blade) are trued by diamonds to the shape of a one-sheet hyperboloid of revolution.

To ensure that a true cylindrical surface is ground on the work, it is set above the centres of the regulating and grinding wheels by an amount equalling 0.15 to 0.25 of the workpiece diameter, but not over 10 or 12 mm (to avoid vibration).

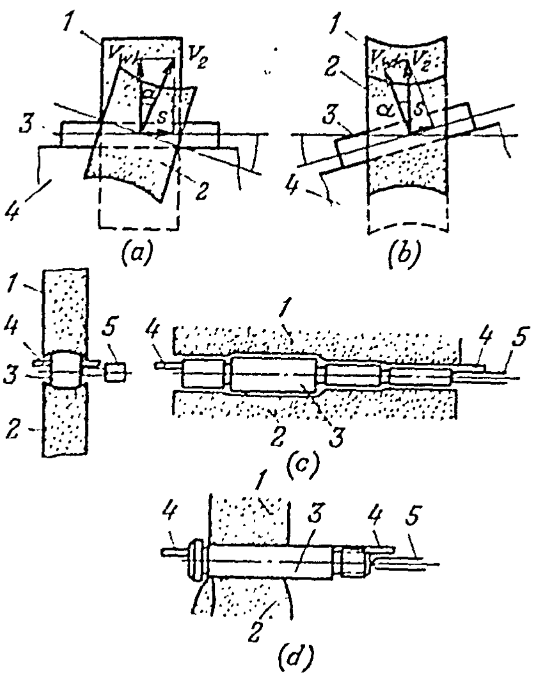


Fig. 232. Diagrams of centreless grinding: 1—grinding wheel; 2—regulating wheel; 3—workpiece; 4—work-rest blade; 5—end stop

Infeed grinding in a centreless grinder (Fig. 232c) involves only rotation of workpiece 3 supported on work-rest blade 4. The cross feed is obtained by a method similar to plunge-cut grinding in which the grinding or regulating wheel is fed in a direction square to the workpiece axis by a precise feed screw. In some cases, the infeed motion is obtained by the use of a regulating wheel of special shape. Its periphery consists of sectors *I*, *II* and *III* (Fig. 233). Sectors *I* and *III* are circular arcs of different radii. Sector *II* is shaped to an Archimedean spiral. This enables infeed to be obtained without movement of the wheelheads. The whole grinding cycle takes place during one revolution of the regulating wheel.

To grind tapered or contoured surfaces in a centreless grinder, the face of the grinding wheel or the faces of both wheels are trued to the required profile. The workpiece is loaded between the wheels from above and the axis of the regulating wheel or the work-rest blade is inclined slightly ($\alpha \cong 30'$) to provide for a fixed axial position of the workpiece between the wheels by holding it against the locating stop. Infeed grinding is done at various rates of infeed and depths of cut. At the beginning of the process, a large part of the allowance is removed with a high rate of infeed. Then the rate is reduced and, at the end of the operation, the workpiece is ground for several revolutions without infeed (sparking out).

End feed centreless grinding (Fig. 232*d*) is essentially a process intermediate between through-feed and infeed grinding. It is employed to grind workpieces having surfaces (tapers, shoulders, etc.) that do not allow it to pass between the wheels. As the workpiece approaches end stop *5*, the work-rest slide and regulating wheel *2* are withdrawn from grinding wheel *1*, and workpiece *3* is removed from the grinding zone. The workpiece may sometimes be removed by the regulating wheel. In this case, the regulating wheel has a longitudinal slot *A* (Fig. 233) into which the finished workpiece drops, after rolling off the work-rest blade, and is carried out of the grinding zone.

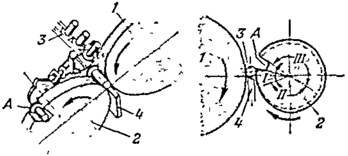


Fig. 233. Automatic infeed centreless grinding with the infeed motion provided by the profile of the regulating wheel

Centreless grinders can be set up to grind a specified size, and the infeed motion can be accomplished by various methods:

(a) Infeed is provided by travel of the work-rest slide and regulating wheel in respect to the stationary grinding wheelhead. The grinding wheelhead possesses high rigidity in these machines. However, it is not always possible to make adjustments to compensate for wheel wear or to change over to the grinding of a different diameter without corresponding displacement and adjustment of the loading and measuring devices (Fig. 234). This limits the use of such machines in automated production lines.

(b) Infeed is provided by travel of the work-rest slide and grinding wheel in respect to the stationary regulating wheelhead. All the inconveniences inherent in the preceding method and associated with travel of the work-rest slide remain in this method and, moreover, the grinding wheelhead lacks sufficient rigidity.

(c) Travel of grinding wheelhead *1* (Fig. 235) provides the infeed motion and compensates for wheel wear. Regulating wheelhead *2* is adjusted to a new diameter of workpiece in respect to stationary slide *3* with the work-rest blade. This slide is secured on the base of the grinder. Such an arrangement facilitates automation of the grinder. In some models, the infeed of the grinding wheel toward the work is accomplished by tilting the wheelhead housing forward (making use of a feed screw) in respect to a pivot arranged in the slide under the grinding wheel spindle. This method of infeed is highly sensitive, enabling movements as small as 2 microns to be made. A hydraulic cylinder serves for rapid approach and withdrawal of the wheelhead. The automatic sizing device is advanced and retracted by another cylinder.

The grinder is set up to a new size of workpiece by adjusting wheelheads *1* and *2*, using screws.

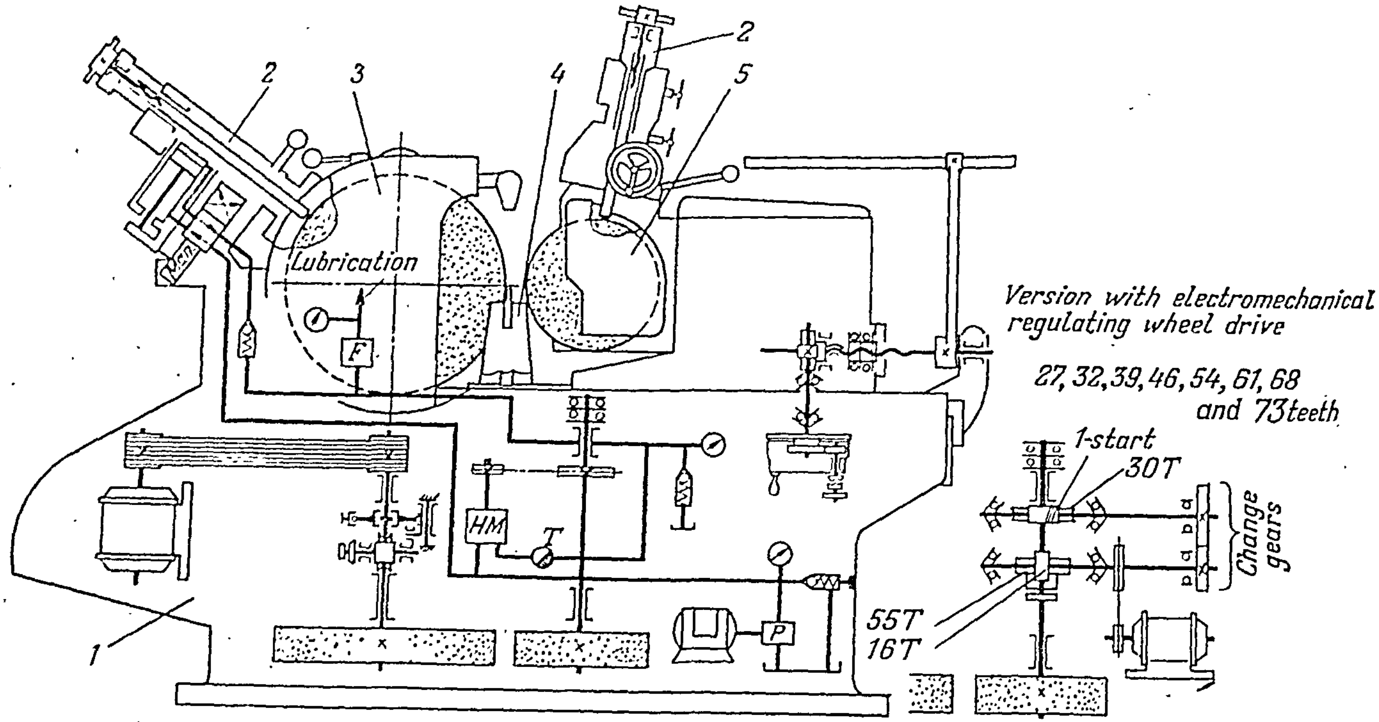


Fig. 234. Centreless grinder with a stationary grinding wheelhead:
1—base; 2—wheel truing mechanisms; 3—grinding wheelhead; 4—slide with the work-rest blade; 5—regulating wheelhead

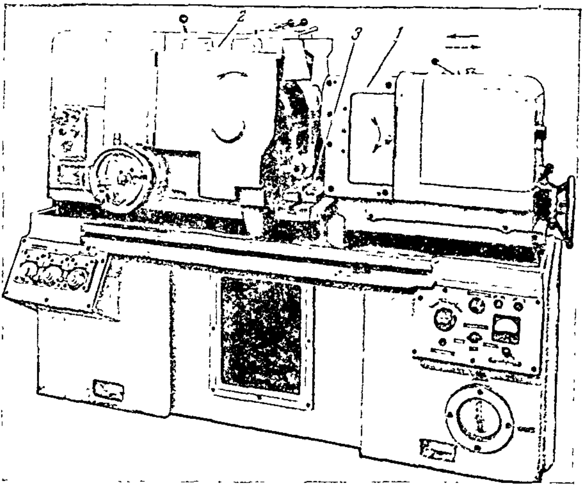


Fig. 235. Automatic centreless grinder, model 3184

The speeds of the regulating wheel drive and of the drive for traversing the truing devices are infinitely variable. A tracer-controlled device is built into the truing mechanism to true the faces of the wheels to a specified profile, as for infeed grinding.

Another machine of this group is the centreless thread-grinding machine in which grinding wheel *1* (Fig. 236) has annular threads, or ribs, of a pitch equal to that of the thread being ground. Through feed, at a rate equal to the thread pitch, is set up by inclining work-rest blade *3* to an angle α equal to the helix angle of the thread being ground on workpiece *2*, and by

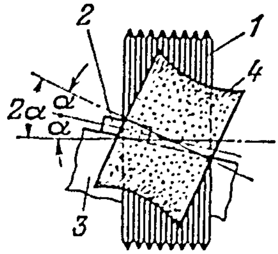


Fig. 236. Centreless thread grinding

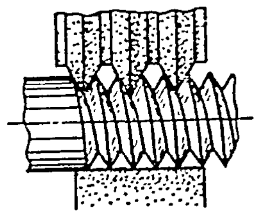


Fig. 237. Grinding thread with a multiple-rib wheel having a rib pitch twice the thread pitch

swivelling the axis of regulating wheel *4* to the angle 2α. Through-feed centreless grinding is used for thread whose length is greater than the face width of the grinding wheel. Short threads are ground by the infeed method.

Threads can also be ground with multiple-rib wheels having a rib pitch that is a multiple of the thread pitch (either twice or thrice the thread pitch) as shown in Fig. 237. In this case, if the infeed method is used, the thread is ground, not in one revolution of the workpiece, but in two (or three).

Two methods of internal centreless grinding are commonly applied. Traverse grinding is used for surfaces with straight elements (tapered or cylindrical). A reciprocating motion is imparted to the wheel in respect to the surface being ground (see Fig. 231).

When the second method, plunge-cut grinding, is employed, only an infeed motion is imparted to the wheel. This method is suitable for contoured internal surfaces, and the wheel is first trued by a diamond to the required profile.

Internal centreless grinders have much in common with ordinary internal grinding machines. The chief difference is that the work is not held rigidly in a chuck. This feature reduces the time lost in aligning the axis of the work with the axis of rotation of the work spindle and in clamping the work in the chuck. As a result, internal centreless grinding is a highly productive process and is finding more and more extensive application in automatic transfer machines and automated production lines.

Machines of this type may operate on an automatic cycle consisting of the following elements: loading the work; clamping the work between the three rolls; rapid approach of the wheelhead to the work and slowing down just before the end of the stroke; insertion of the tips of the automatic sizing device into the hole to be ground; rapid advance of the work crosswise to bring it into contact with the wheel and rough grinding; sparking out

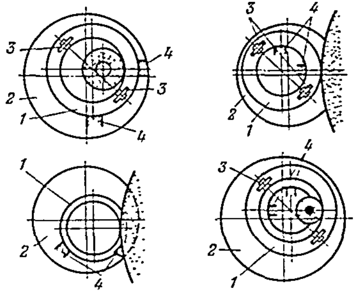


Fig. 238. Diagrams of centreless grinding on supporting shoes

and withdrawal of the wheel from the work; wheel dressing; infeed of the work by the amount of the finish grinding allowance with consideration for the reduction of the wheel diameter in dressing; finish grinding; withdrawal of the wheelhead with the wheel to its initial position; retraction of the sizing device tips from the ground hole; unclamping the work; and unloading.

In one recently developed centreless grinder, the profile of the external surface of a hollow workpiece can be precisely duplicated on the internal surface, or the internal surface on the external surface, as well as the external on the external and internal on the internal surface. In all cases, workpiece *1* (Fig. 238) is held tightly against the face of a rotating faceplate *2* of the machine by means of pressure rolls *3*, and against support shoes *4* due to the offset by a certain amount (0.1 to 0.5 mm) of the centre of rotation of the workpiece in reference to the centre of the faceplate in the direction shown in Fig. 238.

The duplicating accuracy of such machines is very high; the error is within one micron.

In comparison with cylindrical grinders, centreless grinders have the following advantages:

(a) Their output is higher due to the reduction in handling time connected with setting up the work in the grinder and removing the ground work.

(b) Less grinding allowance is required because the workpiece centres itself during operation.

(c) Higher grinding speeds and feeds can be employed, and more metal can be ground off per revolution of the workpiece as there is no danger of bending the work.

(d) More stable dimensions can be maintained in each lot of workpieces.

(e) Work of very small diameter can be ground (external grinding).

(f) Concentric surfaces can be ground to high precision (by the centreless duplicating method).

(g) Less skill is required to operate centreless grinders.

Surfaces with longitudinal slots or grooves cannot be ground in a centreless grinder unless the slots are filled with temporary ("false") keys.

11-5. Mounting and Balancing Grinding Wheels

Proper and reliable clamping of the grinding wheel on the wheel spindle is a prime requisite, both for operator safety and to obtain ground surfaces of the specified accuracy and surface finish. Various methods of wheel mounting are employed (Fig. 239), depending upon the type and construction of the grinder and the shape and size of the wheel.

Wheels of small diameter, used in internal grinding, are either clamped by screws, with the wheel seated either on the screw (Fig. 239*a*), or on the spindle nose (Fig. 239*b*), or they are cemented or glued on a stem (Fig. 239*c*).

Grinding wheels with a small hole are clamped by flanges directly on the spindle (Fig. 239*d*, *e* and *f*). Blotters or washers of an elastic material (cardboard, rubber, leather, etc.) 0.5 to 3 mm thick must be inserted between the flanges and the wheel. The blotters must cover the whole clamping area of the flanges and stick out 3 to 5 mm beyond their outside diameter.

Grinding wheels with a large mounting hole are mounted on an adapter called a wheel sleeve (Fig. 239*g*) which, in turn, is mounted on the spindle. Cylinder wheels are secured on a special chuck *1* either by cementing with soluble glass or bakelite varnish, or by pouring molten sulphur, babbitt or lead into the gap between the wheel and chuck flange (Fig. 239*h*). The surfaces of the wheel and chuck that are joined in this manner must be rough, cleaned of all dirt and degreased.

Segmental wheels are held in their chucks either by cementing or by mechanical clamping, using tapered keys *1* and screws *2* and *3* (Fig. 239*i*). The segments must be clamped on a width (height) less than their thickness.

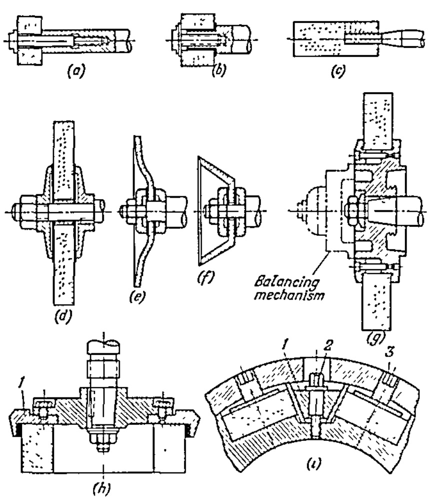


Fig. 239. Methods of mounting grinding wheels on the spindle

Before mounting on the grinder spindle, each wheel with its sleeve should be balanced on an arbor which is placed on the straight edges or revolving disks of a balancing stand (Fig. 240). The wheel is balanced by shifting three balance weights *1* in an annular groove of the wheel sleeve (or mounting flange).

Certain types of grinders are equipped with a mechanism for balancing the wheel during grinder operation without stopping wheel spindle rotation. Figure 241 shows the gearing diagram of a mechanism for balancing the

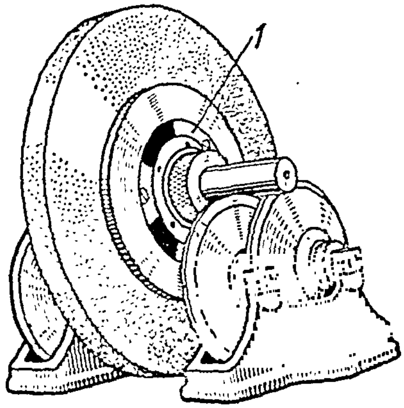


Fig. 240. Revolving-disk wheel balancing stand

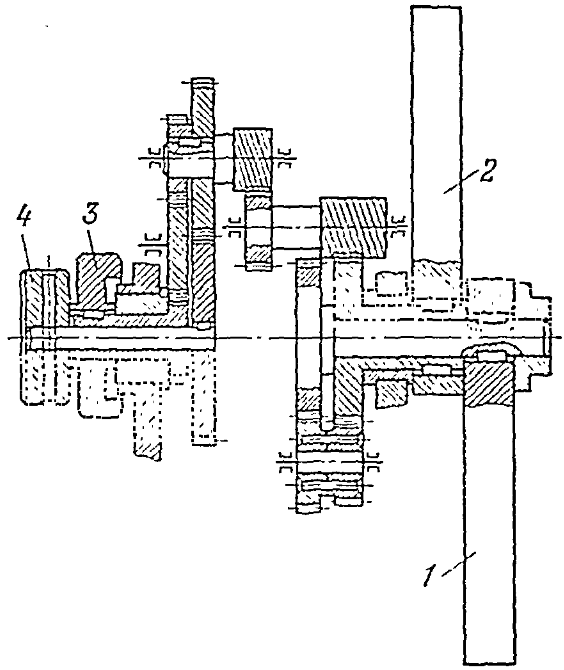


Fig. 241. Gearing diagram of a wheel balancing mechanism

wheel on a cylindrical grinder manufactured by the Kharkov Machine Tool Plant (USSR).

Balancing is done by turning heads *3* and *4* to revolve weights *1* and *2* in the same direction at different speeds. One revolution of the weights corresponds to 128 revolutions of head *4* or 64 revolutions of head *3* in a direction opposite to the rotation of head *4*. This mechanism is mounted in a housing fastened to the wheel flange (see Fig. 239*g*).

The balancing procedure consists in merely holding head *4* until the wheel is properly balanced. If head *4* is not released in time, so that the position of minimum unbalance is passed, then head *3* is held to return the weights to this position.

The position of minimum unbalance is determined by means of vibrometer or by the ripples on the surface of some coloured water poured into a recess on the cover of the wheelhead. Wheelhead vibration will be at a minimum or entirely absent when the wheel is properly balanced.

11-6. Various Types of Grinding Machines

In addition to the general-purpose grinders, a large number of different machines are available for performing definite grinding operations on workpieces of a single type or on a single given workpiece. Single-purpose grinders may be of the single-spindle or multiple-spindle type. The latter may carry several grinding wheels operating simultaneously and used for external or internal grinding of surfaces of revolution, or for grinding flat or contoured surfaces.

The following classification of the most important types of single-purpose grinders is based on the shape of the surface being ground and the purpose of the machines: thread grinders, gear grinders (for more detail, see Sec. 13-7), spline grinders, profile or contour grinders, jig grinders, face grinders, spherical grinders, roll grinders (for grinding mill rolls), edge grinders, optical-projection grinders, tool grinders, various grinding machines for the automotive industries (for grinding crankshafts, camshafts, piston rings, etc.), and machines for grinding the components of antifriction bearings.

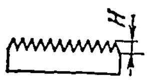
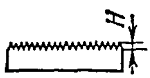
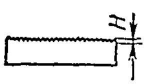
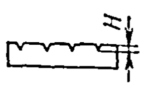
CHAPTER 12

MICROFINISHING MACHINES

12-1. Microfinishing Processes in the Machining of Metals

The necessity for increasing the dependability and service life of modern machinery leads to stricter requirements in specifying the permissible surface roughness of various machined parts. Surface finish has a vital effect on the most important functional properties of machine parts. These include wear resistance, fatigue strength, corrosion resistance and power losses in friction of motion. Thus, intensive wear of rubbing surfaces, if the finish is not good enough, occurs as a result of the rupture of the oil film on the peaks of the microirregularities. This leads to dry friction or to a state approaching dry friction at these places.

TABLE 35

Process	Diagram of resulting surface profile	Designation according to USSR Std GOST 2789-59	Height of microirregularities H, microns
Precision turning		6 to 9б	1.25 to 12.5
Grinding		7б to 9б	0.9 to 5
Honing		9б to 12в	0.13 to 1.25
Lapping		11б to 13б	0.08 to 0.25
Superfinishing		11в to 14в	0.01 to 0.25

The valleys of the microirregularities, as well as the peaks and surface scratches, are stress raisers and may lead to fracture of a part after prolonged operation. Moreover, the sharp profiles of the valleys are conducive to corrosion.

Therefore, microfinishing processes are employed in machining the surfaces of many critical parts to obtain finishes of the higher classes (∇ 10 to ∇ 12 and sometimes higher). Such processes include honing, lapping and superfinishing.

Table 35 indicates the surface finish attainable in the most widely applied microfinishing processes.

12-2. Honing Machines

Honing is the application of bonded abrasive sticks, held on the outside or inside of a honing tool (Fig. 242), to a surface for the purpose of limited stock removal and to obtain a suitable surface finish. The honing tool rotates continuously in one direction and simultaneously reciprocates axially. Feed-out (or feed-in) is accomplished by periodical expansion of the sticks in machining internal surfaces or periodical compression of the sticks (bringing them closer together) in machining external surfaces, for each full stroke of the honing tool.

From 100 to 1,000 times more abrasive grains participate in the cutting process in honing than in grinding; the cutting speed is only $^1/_{50}$ to $^1/_{120}$ of the wheel speed. The pressure of the abrasive tool on the surface being honed is only from $^1/_6$ to $^1/_{10}$ of that in grinding, and is within 2 to 9 kg per sq cm (usually 2 to 6 kg per sq cm). The low cutting speed in honing and the comparatively low pressure provide for a relatively low temperature in the cutting zone. This enables a better surface to be obtained.

Honing is applicable in a wide size range; holes of a diameter as small as 3 mm and as large as 1,000 mm can

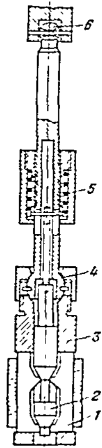


Fig. 242. Honing tool:
1—holders with abrasive sticks; 2—cones for expanding the sticks; 3—body; 4 and 6—universal joints; 5—spring for actuating the expanding cones

TABLE 36

Honing machines	Model	Maximum diameter honed ×length of stroke, mm	Range of honing tool speeds, rpm	Available power, kW	Net weight, kg approx.
Vertical	ОФ-58	20×125	625 to 1,295	1.1	800
	ОФ-50	50×200	200 to 800	1.1	1,300
	ОФ-38А	80×320	200 to 800	1.5	1,450
	3М83	125×500	90 to 240	10 (total)	3,300
	3Б833	165×500	125 to 375	3	1,000
	3Н84	200×1,250	63 to 315	7.5	7,500
	3Н85	320×1,600	25 to 150	13	14,000
	3Н86	500×2,000	25 to 125	22	14,000
	КЖК-43	800×3,000	15 to 45	30	22,000
Automatic two-spindle vertical	ОФ-42	50×320	200 to 800	1.7×2	2,400
	3Б83	200×800	125 to 365	10×2	10,000
Automatic two-spindle horizontal	РТ-57	85×5,000	125 to 500	10	25,000
	РТ-190	175×6,000	20 to 250	22	25,000
	РТ-82	200×5,200	20 to 250	22	25,000
	3826	400×10,000	15 to 100	20	80,000

be successfully honed. These are not, however, limiting values. The length of the honed surface may reach 30 m in some cases.

Depending upon the diameter being honed and the size of the abrasive sticks, the honing tool may hold from 1 to 12 sticks (in one row). Honing is employed for finishing, not only plain cylindrical surfaces, but surfaces with keyways, splines, ports of various shapes, etc. Tapered surfaces and certain types of flat and contoured surfaces can also be honed.

In addition to the high class of surface finish it produces, honing also corrects certain errors in the geometrical features of the surface, such as taper, out-of-roundness, barrel shape of holes, etc.

In the honing process the abrasive sticks are guided by the previously machined surface; the honing tool is allowed to float by linking it to the machine spindle through a universal joint (see Fig. 242). Due to this floating

action of the tool, the attainable machining accuracy does not depend upon the accuracy of the honing machine to any appreciable extent.

Honing machines may have one or several vertical, horizontal or inclined spindles. Both general, and single-purpose models are available. The general-purpose honing machines manufactured in the Soviet Union are listed in Table 36.

Parts up to 2,000 mm long are honed, as a rule, in vertical machines; longer parts are honed in horizontal machines.

Conditions for cooling the honing tool and carrying away the chips are more favourable in the vertical machines since the coolant (soluble-oil emulsion or kerosene) is more uniformly distributed over the surface being machined. In the horizontal honing machines, the coolant is delivered to the rear end of the slowly rotating workpiece through a closed guard and is drained from the front end.

Bending of the arbor carrying the honing tool is avoided by the use of travelling support carriages.

The honing tool is rigidly mounted in horizontal machines designed for honing small short workpieces. The workpieces are held in the hands or are clamped in a floating fixture.

The gearing diagram of the spindle drive in a honing machine differs only slightly from that of an upright drill press (see Fig. 121).

The reciprocating motion of the spindle of a vertical honing machine is most often obtained by means of a hydraulic drive, similar to the drive of a slotter (see Fig. 201), but differing in that the honing spindle travels at the same speed in both directions.

The following types of drives are employed to impart the longitudinal motion to the honing tool of a horizontal machine: electromechanical with a rack-and-pinion or rack-and-worm drive as the concluding link; rope or chain drive; and hydraulic drive.

In the vertical machines for external honing, both the rotary and reciprocating motions are imparted to the honing tool. In horizontal external honing machines, the workpiece rotates while the honing tool only reciprocates.

A new honing technique that makes u [illegible] plane of cutting, called *vibration honin* [illegible] years. It differs from ordinary honing in [illegible] a frequency of 200 to 500 full strokes per [illegible] 2 to 50 mm is added to the reciprocating motion of the honing tool. This reciprocating motion can be much slower than in the ordinary machines.

Vibration honing can produce a better finish than the ordinary type; there is also less tendency to glazing of the abrasive sticks.

12-3. Lapping Machines

Lapping is a final machining operation, applied to produce a very smooth surface, and consists in charging the surface of the work or tool (called the lap) with special abrasive pastes or loose-grain abrasive flours mixed with oil or similar fluid.

The nature of the relative motion in lapping depends upon the shape and other features of the surface being lapped. Slightly differing motions are imparted to the workpiece and the lap so that the path of the abrasive grains of the lap is not repeated on the work. This leads to uniform performance and high production in the lapping operation (sufficiently rapid metal removal from the surface being lapped). The surface obtained will not only have an excellent finish, but will be highly accurate as well.

Metal removal in lapping usually ranges from 0.003 to 0.03 mm, but may reach 0.08 or 0.1 mm in certain cases.

Lapping media include abrasive flours (diamond dust, boron carbide, silicon carbide, aluminium oxide and emery) and pastes or compounds (chromium oxide, aluminium oxide, crocus and Vienna white) mixed with an oil or bonding vehicle (gasoline, kerosene, petroleum or vegetable oils, as well as animal fats).

Laps are made from cast iron (grade СЧ 18-36 or СЧ 21-40), soft steel, copper, brass, hardwoods, as well as hardened steels and glass. Copper and steel laps enable the lapping process to be speeded up; cast-iron laps retain their shape better and produce a smoother surface; glass laps have a high metal-removal capacity if used with fine-grain abrasive, and produce an even better surface than cast-iron laps. The finest finish is obtained in finish lapping if the laps are made of hardwoods (beech, oak, etc.).

Lapping machines of the general-purpose (Table 37) and single-purpose types are available. The single-purpose types include machines for lapping valve seats, crankshaft crankpins and journals, camshafts, gears, etc.

Cylindrical and flat surfaces are most frequently finished in general-purpose machines having one or two laps. The workpieces are placed in the openings of a retainer or spider, the shape of the openings depending upon that of the workpieces. The retainer with the workpieces is arranged eccentrically between two lapping disks, or laps (Fig. 243*a*). Due to the relative sliding motion which is the result of the different speeds of the laps and work retainer, as well as the pressure applied to the surface by the laps, the abrasive grains with which the laps are charged remove fine particles of metal from the surface. The retainers are made of soft materials (laminate fabric base, copper, etc.) to avoid damage to the surface being lapped.

Machines with a single lapping disk are used to lap comparatively large flat surfaces. The work is clamped in a fixture to which a rocking motion

TABLE 37

Type of machine	Model	Lap diameter or maximum diameter and length of workpiece, mm	Lap or work speed, rpm	Available power, kW	Net weight, kg approx	Remarks
Vertical-axis lapping machines:						
single-lap	3804	360	40	1.1	250	—
	3806	710	35 to 70	2.2	280	—
	3807	1,100	40	7.5	750	—
	3808	1,600	29	13	1,000	—
double-lap	3814П	450	45 to 86	5.5	2,500	Upper pressure lap, lower rotating lap
	3816П	710	30 to 99	5 5/7.5	4,300	
	3817	1,100	20 and 40	13	7,000	
two position	МШ-156	700	50 to 100	5 2/7×2	6,600	Both laps rotate, hydraulic pressure
Cylindrical superfinishing machines	ВС-22	320×630	15 to 690	1	1,900	Traverse and oscillating motions performed by stone-holder heads
	ВС-23	320×1,400	15 to 690	1	2,300	
	ХШ-136	560×2,800	10 to 500	3	8,000	With two stone-holder heads; based on cylindrical grinder
Automatic crankshaft superfinishers	2К34	400×1,100	43 to 130	4	1,600	Simultaneous machining of all pins and journals with abrasive stones
	2К35	400×1,600	30 to 91	4	1,700	

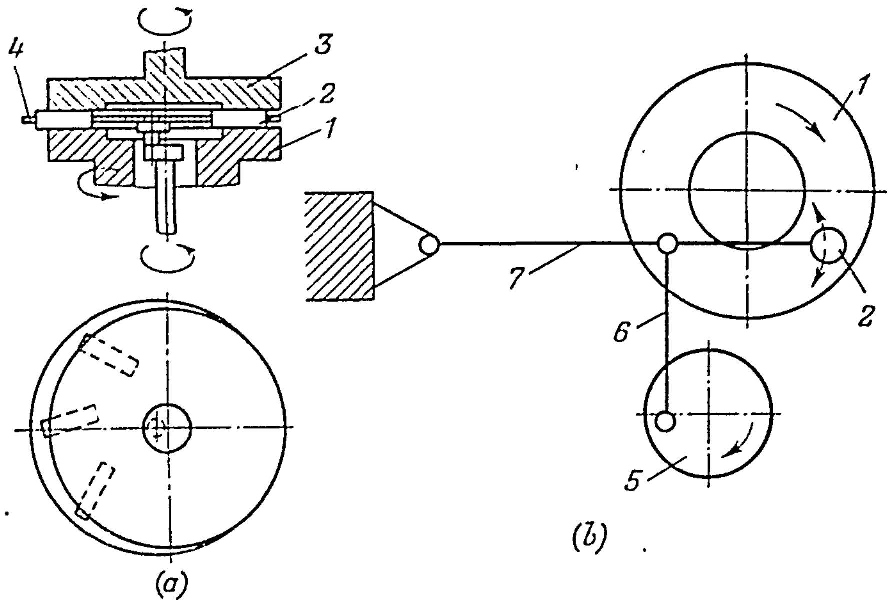


Fig. 243. Principle of lapping machines:
(a) with two laps; (b) with one lap; 1—lower lap; 2—workpiece; 3—upper lap; 4—retainer (work holder); 5—crank disk (with adjustable crankpin radius); 6—connecting rod; 7—rocker arm

is imparted on the surface of the rotating lap by means of a driving member (Fig. 243b).

The combined hydraulic circuit and gearing diagram of the model 3Б816 general-purpose lapping machine is shown in Fig. 244.

The lower lap *10* is powered from a two-speed motor through a V-belt drive with change pulleys (shaft *I*) and worm gearing $\frac{3}{50}$. Rotation of the second lap *11* is transmitted from shaft *I* through a second worm gearing unit $\frac{3}{50}$, and spur gearing to shaft *IV*. From here it can be transmitted further by sliding gear 33*T* to shaft *V* and a V-belt drive to spindle *VI* of upper lap *11*. Sliding gear 33*T* has four different positions on shaft *V*. In position *a*, the upper lap rotates in the same direction as the lower lap but at a speed 10 per cent slower. When gear 33*T* meshes with gear 41*T* (position *c*) the upper lap rotates in the opposite direction from lower lap *10* and at a speed higher by 10 per cent. The intermediate position *b* of gear 33*T* is used when a free upper lap is required. To operate with a stationary upper lap, gear 33*T* is meshed with a stationary rack (position *d*).

In lapping flat surfaces, the retainer with the workpieces has a positive drive from a separate motor (1 kW, 930 rpm) through an infinitely variable

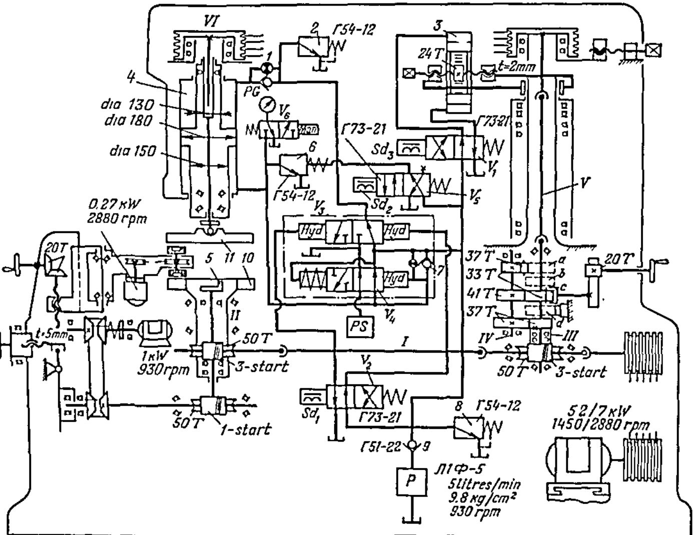


Fig 211. Combined hydraulic circuit and gearing diagram of the model 3Б810 lapping machine

transmission (V-belt variable-speed drive), worm gearing $\frac{1}{50}$ and the eccentric pin (crankpin) *5*.

The lapping disks are trued by fine-grain grinding wheels driven from a separate motor (0.27 kW, 2,880 rpm).

The lapping machine operates on the following cycle. When the OVERARM UNCLAMP push button is pressed, solenoid Sd_3 of valve V_1 is energized. Oil is delivered by pump P through check valve *9* and the left position of valve V_1 to the lower end of overarm clamping cylinder *3*. This releases (unclamps) the overarm. The upper lap, together with the overarm, can be swung to one side to load workpieces into the retainer. After this, the overarm is returned to the working position and the SPINDLE DOWN push button is pressed. At this, solenoid Sd_3 is de-energized and the overarm is reclamped. At the same time, solenoid Sd_1 of pilot valve V_2 is energized, shifting the valve spool to the right. This shifts the spool of valve V_3 to the right position.

Oil passes through the right position of valve V_3 and cushioning valve *1* to the upper end of hydraulic cylinder *4* and simultaneously through check valve *7* to the lower end of the same cylinder. Since the upper end of the cylinder has a larger effective area, the resultant force acting on the piston is directed downward. The piston begins to travel downward forcing the oil from the lower end through valve V_4 and into the upper end of the cylinder. Under the action of the oil forced out of the cylinder, the spool of valve V_4 is shifted to the right position, thereby connecting pressure switch PS with the tank. The spool of valve V_4 is held in its right position as long as the piston of cylinder *4* continues to travel downward. As soon as the piston with the upper lap stops, after reaching the workpieces, the flow of oil between the cylinder ends ceases. Then the spool of valve V_4 is shifted to the left by spring action and connects pressure switch PS to the oil under pressure. The switch transmits commands to start lap and retainer rotation. It also energizes solenoid Sd_2 of valve V_5 and de-energizes solenoid Sd_1. As a result, the upper end of hydraulic cylinder *4* is connected to the tank and the pressure in its lower end will be determined by the setting of valve *6* which was previously closed. Thus the upper lap is suspended and floats on the work while the laps accelerate until they reach the working speed. At the end of this acceleration, solenoid Sd_1 is energized and solenoid Sd_2 is de-energized. Then lapping begins at the required working pressure and continues for a period of time determined by a time-delay relay. After this, "sparking out" occurs (lapping at reduced pressure due to the de-energization of solenoid Sd_1 and energization of Sd_2) for a period that is also determined by a time-delay relay.

At the end of the "sparking out" period, the laps and retainer stop rotating. At the same time, solenoid Sd_2 is de-energized and valve *6* is closed

so that the pressure increases in the lower end of cylinder *4* and the upper lap is raised. Oil from the upper end of cylinder *4* drains through the left position of valve V_3 to the tank (since solenoid Sd_1 is de-energized).

Valve *8* protects the system against overloads; valve *2* regulates the lapping pressure. Valve V_6 switches in the pressure gauge.

12-4. Superfinishing Machines

Superfinishing is used to obtain a surface of the highest class of finish. This process is similar to honing with small allowances but differs in the large number of different tool (abrasive stones and wheels) and work motions involved (sometimes up to 12); the lower cutting speeds at lower pressure of the stones on the work surface (usually 0.5 to 4 kg per sq cm) and the negligible increase in temperature of the surface layers of the work.

A notable feature of superfinishing is the sharp reduction in metal removal after the ridges and peaks produced by previous machining have been removed. At the beginning of the process, even a low pressure is sufficient to rupture the oil film due to the sharp peaks of the surface irregularities. When the contact area is increased in the course of operation, and a smooth enough area has been developed on the metal surface, the pressure proves insufficient to rupture the oil film and the viscosity of the oil balances the pressure of the stone. At this point metal removal ceases and indefinitely continued action will not remove even a minute amount of additional material.

Superfinishing allowances range from 0.002 to 0.02 mm. Surfaces that are to be superfinished must be previously machined to the 8th or 9th class of surface finish. Superfinishing can be applied to external and internal cylindrical, tapered, flat and spherical surfaces. External cylindrical surfaces can be superfinished by oscillating stones, reciprocating axially along the rotating workpiece (Fig 245*a*), or by stones, oscillating and rotating about the stationary workpiece (Fig. 245*b*) Internal cylindrical surfaces are superfinished by axially oscillating and reciprocating stones applied to the rotating workpiece (Fig. 245*c*) In superfinishing flat surfaces, the face of a cup wheel or side of a straight wheel is applied to the work which is held on a table. Both the wheel and the table with the work rotate and, at the same time, describe a circular (planetary) motion about axes that do not coincide with their axes of rotation (Fig. 245*d*)

Of the great variety of motions used in superfinishing, the most typical is the oscillating movement in a direction that is perpendicular, as a rule, to the scratches produced by previous machining operations

The many different working motion setups and the large variety of shapes handled have led to the development of superfinishing machines with differ-

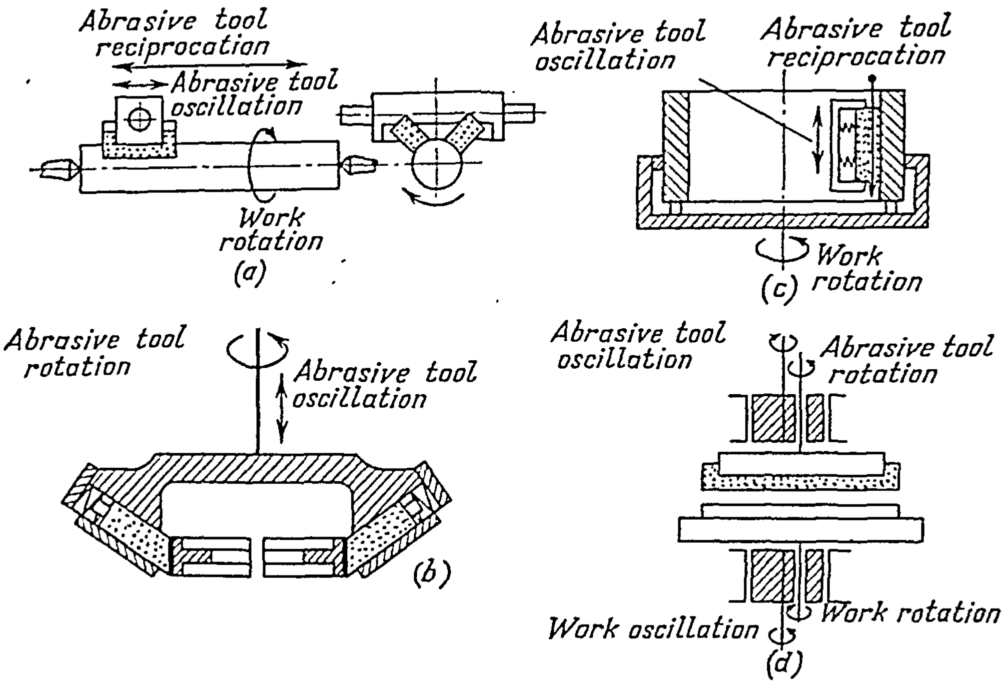


Fig. 245. Motions of the tool and work in superfinishing

ent construction arrangements. Most models are intended for accommodating workpieces of a definite kind (see Table 37).

General-purpose superfinishing machines for round work are usually based on a definite model of a cylindrical grinder having one or two stone-holders (heads) with oscillating abrasive stones. The traverse motion is obtained by longitudinal travel of the work table.

In superfinishing machines designed for small-size parts, the traverse motion is accomplished by the stone-holders simultaneously with the oscillating motion.

The longitudinal motion (traverse) in superfinishing machines is usually powered by a hydraulic drive similar to that of a cylindrical grinder (see Fig. 219). The oscillating motion of the heads is frequently obtained by an eccentric cam driven by a separate motor, but pneumatic or hydraulic drives can be used for this purpose as well.

CHAPTER 13
GEAR-CUTTING MACHINES

13-1. Gear-Cutting Methods

The two principal methods employed at present in the manufacture of toothed gears are: form cutting and generating.

Form-cutting process. This method makes use of a cutting tool whose cutting edges have been formed to the shape of the tooth space to be cut. Examples of such tools are gear-tooth milling cutters of the disk or end-mill type (Fig. 246*a* and *b*) and form tools (Fig. 246*c*).

If a single tool is employed, the cutting of the spaces alternates with indexing, i.e., turning the blank to the next tooth space or $\frac{1}{z}$ revolution, where z is the number of teeth on the gear being cut. The production capacity of this method is low since each tooth space is machined separately, and time is lost in returning the tool to its initial position and in indexing the gear blank.

Moreover, since the tooth profile depends upon the module, pressure angle and number of teeth, it is theoretically necessary to have a tool with a special profile (milling cutter or form tool) for each gear with a different number of teeth or module. In actual practice, however, sets of gear-tooth milling cutters are used (8 cutters per set or, for more accurate gears, 15 and, less frequently, 26 cutters) for each module of gear. Each cutter in the set is designed for cutting a limited range of numbers of teeth. Gears cut by this method are not very accurate since, in addition to the errors associated with inaccurate operation of the indexing mechanism, there are inevitable errors inherent in the cutting tool. In consequence, this gear-making method is

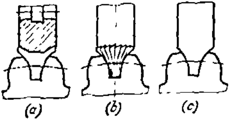


Fig. 246. Gear manufacture by the form-cutting process:
(a) with a gear-tooth cutter; (b) with an end-mill type gear milling cutter; (c) with a form tool

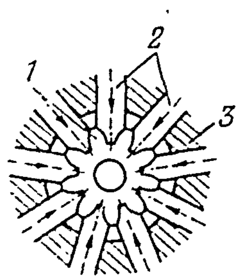


Fig. 247. Principle of the multiple-tool shaping cutter head:
1—gear blank; 2—form tools; 3—body of the head

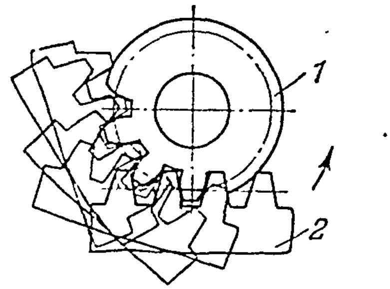


Fig. 248. Generation of involute profiles:
1—gear blank; 2—cutting tool

resorted to in regular production only if a gear-cutting machine is not available. It is used, however, in repairs, in making single gears, in some cases for cutting herringbone gears, and in roughing the tooth spaces (in roughing operations).

In mass production the form-cutting principle is applied in the multiple-tool shaping cutter head (Fig. 247) used to cut all the tooth spaces of a gear at the same time. This cutter head has as many radially arranged form tools as there are spaces (or teeth) on the gear being cut. The profile of the tools is exactly of the some shape as the gear-tooth spaces. During each full stroke (cutting and return) of the cutter or gear blank (in a direction perpendicular to the plane of the drawing) each tool is fed radially toward the blank, by an amount equal to the infeed, prior to each cutting stroke. All the tools are simultaneously retracted from the work on the return stroke to avoid rubbing of the tool clearance surfaces against the machined surfaces. All the tooth spaces are cut simultaneously, and the gear is finished when the tools reach their full depth of cut.

The production capacity of this gear-cutting method is very high and the accuracy of the cut gears depends only upon the accuracy of the cutter head which may be sufficiently high. Drawbacks of this method are the comparatively complex manufacture of the cutter heads and the necessity of having a separate head for each size of gear.

Another high-production form-cutting process used in gear making is broaching which is economically justified only in the mass production of identical gears. Broaching produces highly accurate gears with an excellent surface finish.

The generating process. This method is based upon the meshing of the cutter with the gear being produced to develop the tooth by the relative

rolling motion of the cutter *and the work*. For this purpose the cutter is shaped like a gear, gear rack or worm, i.e., a part which could mesh with the gear being cut, or the tool is made so that its cutting edges describe in space the surfaces of the tooth profiles of a *certain imaginary* gear or rack, known as the generating gear or rack. In this *meshing action of the work and tool*, to which an additional cutting motion is imparted, the *cutting edges of the tool*, gradually removing material from the tooth spaces, shape the *gear teeth to profiles that* are the envelope of the consecutive positions of the *cutting edges of the tool* (*Fig.* 248).

Though the generating method cannot compare in output with form cutting, as used in the multiple-tool shaping cutter heads or in broaching, *it is much* more universal. A tool of a certain module, operating by the *generating principle*, can cut gears with any number of teeth of the same module, including modified *gears*.

13-2. Gear-Cutting Machine Classification

Gear-cutting machines can be classified according to the following features:

(1) The type of machining and tool used: into gear hobbers, gear shapers, gear planers, gear-broaching machines, gear-shaving machines, gear grinders, gear lappers, gear-tooth honers, and gear-tooth rounding machines.

(2) Purpose: into machines for cutting spur and helical gears, worm wheels, herringbone gears, gear racks, straight bevel gears, and curved-tooth bevel gears.

(3) The finish of the machined tooth surfaces: into machines for roughing the teeth, for finishing the teeth, and for microfinishing the active surfaces of the teeth.

13-3. Gear-Hobbing Machines

Semiautomatic gear-hobbing machines are the most commonly used machines in gear manufacture. This is due mainly to their comparatively high production capacity, versatility and sufficiently high accuracy.

Figure 249 illustrates a universal semiautomatic gear hobber. Gear hobbers can cut external spur and helical gears, as well as worm wheels. Certain models permit the cutting of spline shafts, as well as other parts having projections, recesses or flats of identical shape, equally spaced about the periphery of the part, at the same distance from the centre (Fig 250).

Gear hobbers can also cut internal gears of sufficiently large size. This requires a special attachment operating by the form-cutting method and

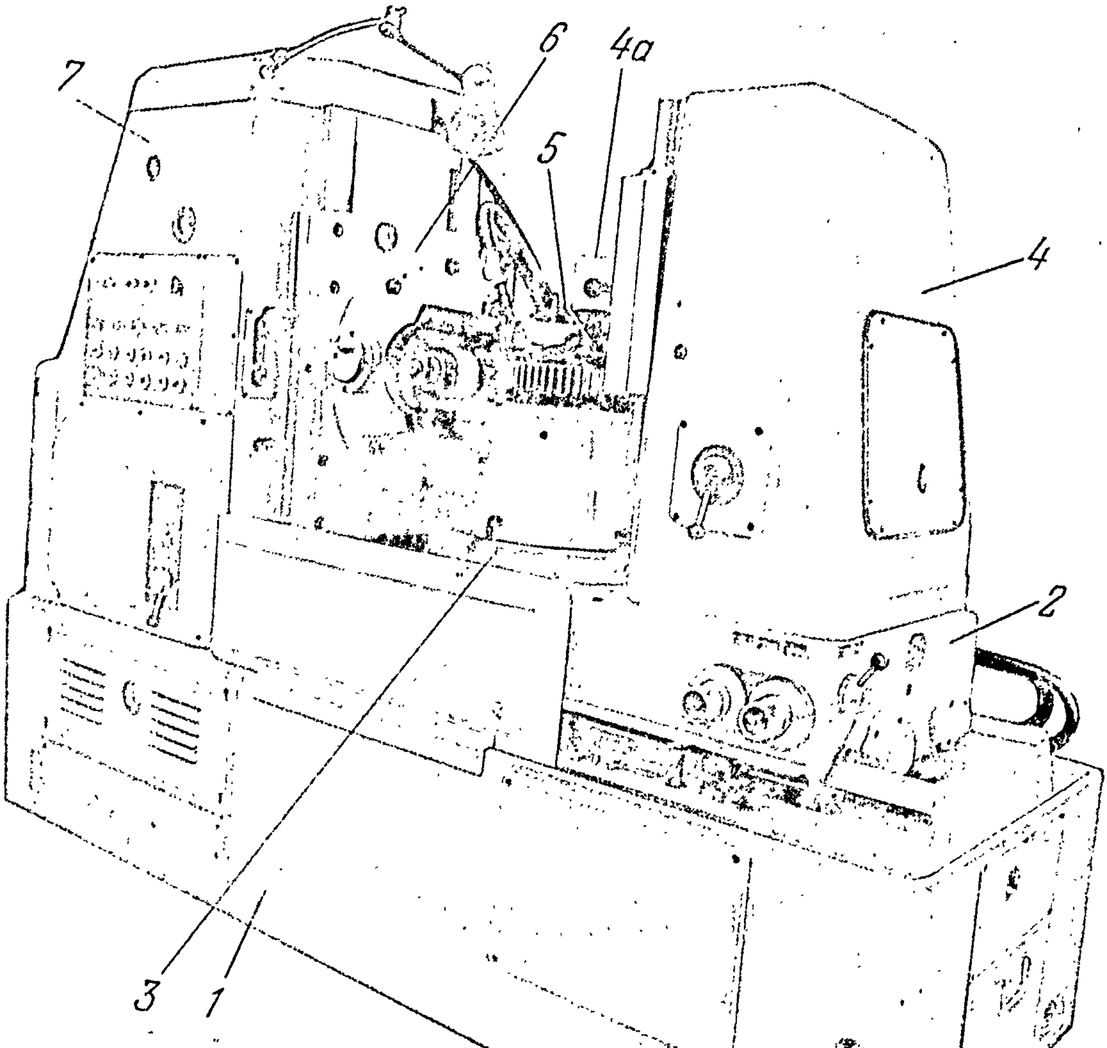


Fig. 249. Universal semiautomatic gear-hobbing machine, model 5K32П: 1—bed; 2—table saddle; 3—circular work table; 4—work-arbor support with arm 4a; 5—work arbor; 6—hob slide; 7—stanchion

a mechanism for manual indexing of the blank from tooth to tooth. Internal gears are very rarely cut in gear hobbers; they can be cut more accurately and much faster in a gear shaper.

Notwithstanding the great variety of types and sizes, all gear hobbers have the same elementary gear train (Fig. 251).

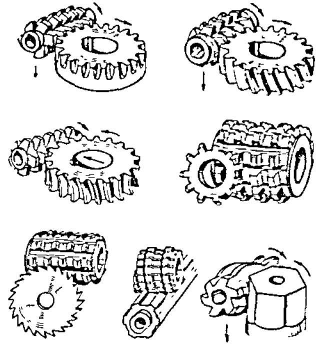


Fig. 250. Various workpieces that can be hobbed

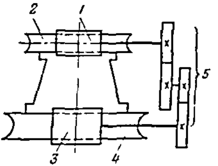


Fig. 251. Elementary hobbing-machine gear train:
1—hob, 2—worm wheel blank; 3—index worm 4—index worm wheel, 5—change gears

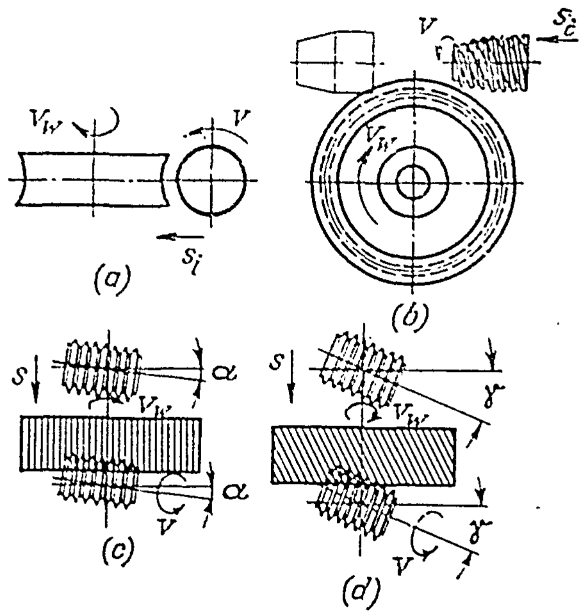


Fig. 252. Basic hob-feed directions:

(a) cutting a worm wheel with radial infeed of the hob; (b) cutting a worm wheel with tangential feed of the hob; (c) cutting a spur gear with axial feed; (d) cutting a helical gear with axial feed

Gear hobbers operate on the generating principle. The rotary motions imparted to the gear blank and cutting tool (hob) are the same as those of the worm wheel and worm in worm gearing. The gear blank is rigidly attached to the index worm wheel which is driven by the index worm. The latter is linked kinematically to the hob by means of change gears. The required ratio of hob and blank speeds is established by the change gears in such a manner that during one revolution of the hob the blank turns through as many teeth as there are starts (threads) on the hob, i.e., the blank must make $\frac{k}{z}$ revolutions per revolution of the hob, where k is the number of starts on the hob and z is the number of teeth on the gear being cut. In addition to the continuous indexing motion, it is necessary to obtain on the machine the primary cutting motion, feed motion and motions for tentatively setting the tool and blank in the initial working positions. Consequently, the actual gear train of a gear hobber includes mechanisms which determine the kinematic features of the various models of gear hobbers (for a more detailed discussion see Vol. 2, Part Three, Sec. 5-3).

In cutting worm wheels the axis of the hob is set perpendicular to the axis of rotation of the blank (Fig. 251). The following principal motions are

required for this operation (Fig. 252): principal rotary cutting motion v of the hob, rotary motion v_ω of the gear blank *(continuous indexing motion)*, and feed motion which can be either radial infeed s_t (Fig. 252*a*) or tangential feed s_t (Fig. 252*b*). Radial infeed ceases when the full depth of cut is reached. If tangential feed is employed, the hob is set at the beginning to the full depth of cut and it feeds into the blank by an axial feed motion.

The radial infeed method has a higher production capacity. However, a comparatively few hob teeth cut each tooth on the gear, producing more or less visible flats that reduce the tooth profile accuracy. Furthermore, in radial infeed only a small part of the hob length is actually doing the cutting. As a result, the hob wears nonuniformly. This also has an unfavourable effect on the tooth profile accuracy.

If multiple-start hobs are employed, or if high gear accuracy is required, the tangential feed method is used. It can be used, however, only when a special hob slide is available to transmit power axial travel to the hob. Single-tooth fly-cutting hobs (Fig. 253*a*), or tapered hobs (Fig. 253*b*), or cylindrical hobs with a tapered entering end are used in tangential feed gear cutting

Fly-cutting hobs (also called fly cutters) are used in piece production since they are considerably cheaper than hobs. Cylindrical hobs with a tapered entering end and tapered hobs wear uniformly since they cut along their full length. The high tooth profile accuracy attainable in tangential feed gear cutting is due to the large number of hob teeth that cut each tooth of the worm wheel.

To cut spur or helical gears the hob is set so that the threads of the hob on the side facing the gear blank are directed along the axes of the tooth spaces when spur gears are being cut (vertically in the most common type of gear hobber), and at the helix angle β of the teeth when helical gears are being cut. This is done by setting the hob axis, in the first case, at an angle

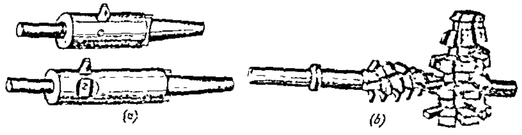


Fig. 253. Fly-cutting hobs (a) and tapered hobs (b)

TABLE 38

Type of machine	Model	Maximum diameter of blank, mm	Maximum module cut, mm	Range of hob spindle speeds, rpm	Power of drive motor, kW	Net weight, kg approx.	Remarks
Automatic gear hobber	530A	25	1	330 to 1,930	0.6	360	Horizontal blank axis. Travelling hob slide carriage
Semiautomatic gear hobbers	530П	50	1	200 to 2,000	0.5	350	Vertical travel of blank. Radial infeed of hob slide saddle
	5308A	80	1	63 to 400	1	1,500	
	5K301Б	125	2.5	115 to 500	1.7	1,300	
	5306K	200	5	90 to 450	5.5	3,000	Vertical blank axis. Moving table type
	5307K	320	6	100 to 400	7.5	4,500	
	5K324A	500	8	40 to 310	7.5	6,200	
	5K32П	800	10	40 to 310	7.5	7,200	
	5K328П	1,250	12	40 to 200	14	12,800	Vertical blank axis. Moving stanchion type
	5A342П	2,000	20	18 to 100	14	22,800	
	5343П	3,200	30	10 to 60	25	9,800	
	5345	5,000	30	10 to 60	25	18,600	
	5346	8,000	40	10 to 60	25	200,000	
	5348	12,500	40	10 to 60	25	200,000	

Semiautomatic horizontal spline hobber	5350B	Diameter 150, length 700 to 2,000	8 to 250	7.5	3,900 to 4,600	
Horizontal gear hobbers	5A370П	Diameter 500, length 2,000 to 3,000	16 to 100	14	22,000	Horizontal blank axis. Travelling hob slide carriage
	5373A	Diameter 800, length 4,000	10 to 60	25	49,000	
	5A375	Diameter 1,250, length 5,600	10 to 60	20	68,500	
		Centre-to-centre distance × maximum module, mm				
Hobbers for making globoid worms and worm wheels	(E3-57)	320×12	11 to 189	7.5	6,900	Radial infeed of stanchion in roughing
	548	800×26	0.01 to 45	13	30,000	Rotary feed of table in finishing
	549M	1,600×50	0.002 to 25	17	60,000	

α to the horizontal, equal to the helix angle of the hob (Fig. 252*c*). In the second case, the hob is set at an angle $\gamma = \beta \pm \alpha$, where β is the helix angle of the helical gear being cut (Fig. 252*d*). If the hand of the helical gear and that of the hob are different (one right-hand and the other left-hand), the plus sign should be used in the above equation; if the hand is the same, the minus sign should be used.

The feed motion s in cutting spur and helical gears is the travel of the hob along the axis of the gear blank (Fig. 252). In cutting helical gears an increment motion is imparted to the table with the gear blank, with an angular velocity that would provide one full additional revolution of the blank during vertical feed of the hob through a distance equal to the lead of the helical teeth on the gear.

The principal dimensions of a gear hobber are the maximum diameter and module of gear that can be cut (Table 38).

Depending upon the disposition of the blank axis, gear hobbers may be either vertical or horizontal models.

Horizontal hobbers are intended chiefly for cutting pinion shafts (in which the gear is integral with its shaft) and spline shafts. The hob is set to the depth of cut and the feed in these machines is accomplished by motions of the cutter head.

Vertical hobbers have either a moving work table or a moving hob slide stanchion. In the moving table models, the hob is set to the depth of cut and fed into the blank by travel of the table with the gear blank. In the moving stanchion models, positioning motions and radial infeed are accomplished by travel of the stanchion with the hob slide and hob.

13-4. Setting Up and Holding the Gear Blanks in Hobbing

The accuracy with which gear teeth are cut depends for the most part upon the accuracy with which the gear blank is set up in the machine. Therefore, the locating hole axis or shaft axis of the blank must coincide, and the locating face of the blank must be square, with the axis of rotation of the work table within specified tolerances when the blank is set up on the hobber table.

In clamping the blanks, they must be supported as near as possible to the point of application of the cutting force. This provides for dependable clamping, precluding all shifting of the blank under the action of the cutting force.

The setting-up accuracy is checked with a dial indicator, the contact point of which is applied either to the mounting (locating) hole of the blank

or shaft journals, or to the outside surface of the blank (to measure radial runout), as well as to the locating face of the blank.

Radial runout of the gear blank may be due to a lack of concentricity between the locating and outside surfaces, or misalignment of the axis of the locating surface and the axis of table rotation. The first of these cases has no significant effect on the accuracy of the gear being cut since the pitch circle will be concentric with the locating surface.

Radial runout, due to misalignment of the axis of the locating surface and that of table rotation, should be maintained at a minimum value and should not exceed the values listed in Table 39.

TABLE 39

Grade of accuracy of gear being cut according to USSR Std GOST 1643-56	Maximum permissible radial runout, microns, in hobbing a blank of diameter, mm				
	up to 200	*up to 800*	*up to 1,200*	*up to 2,000*	*up to 4,000*
6	20	35	50	70	100
7	35	60	80	130	200
8	50	80	100	150	250
9	110	180	220	300	500

Side runout of the gear blank, due to inaccurate setting up on the hobber table (misalignment of the work supports, dents on the locating or seating surfaces, chips or dirt under the locating surface of the blank, etc.), should not exceed the following permissible values (where F = permissible radial runout of the outside diameter, microns; D_{ro} = diameter of the circle on which the side runout is checked, mm; and b = face width of the gear, mm):

Grade of accuracy of gear being cut according to USSR Std GOST 1643-56	6	7	8	9
Permissible side runout	$0.15\,F\,\frac{D_{ro}}{b}$	$0.2\,F\,\frac{D_{ro}}{b}$	$0.25\,F\,\frac{D_{ro}}{b}$	$0.3\,F\,\frac{D_{ro}}{b}$

The method used to hold the blank depends upon the size, construction and required accuracy of the gear to be cut. Figure 254 illustrates typical

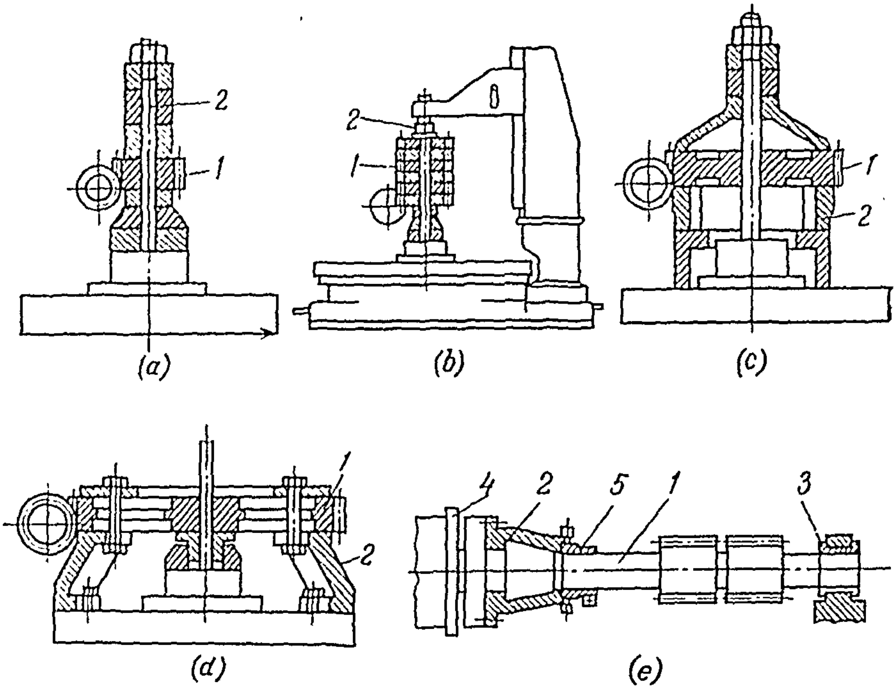


Fig. 254. Methods of holding the gear blanks in hobbing machines

methods of holding gear blanks in hobbing machines. Small gear blanks *1* with a locating hole can be held either separately (Fig. 254*a*) or in a stack (Fig. 254*b*) on a rigid arbor, or mandrel, *2*, which may have a pilot at the upper end that is supported in the bushing of the work-support arm. Large and medium-size gears *1* are held on cast-iron supports *2* in the form of feet or rings (Fig. 254*c* and *d*). If pinion shafts *1* are cut in the horizontal type of hobber, one end of blank *1* is secured in fixture *2* (Fig. 254*e*) and the other is supported in bushing *3* of the support bracket. The blank is rotated by faceplate *4* through the body of the fixture and detachable driving dog *5*.

13-5. Gear Shapers

Semiautomatic and automatic gear shapers cut external and internal spur and helical gears, cluster gears, flanged gears, toothed clutches, gear racks, ratchet wheels, cams, etc.

In this general type of gear-cutting machines, the cutting tool resembles either a gear rack and is called a *rack-type cutter* (Fig. 255*a*), or a gear, in which case it is called a *rotary gear shaper cutter* (Fig. 255*b*). Gear shapers

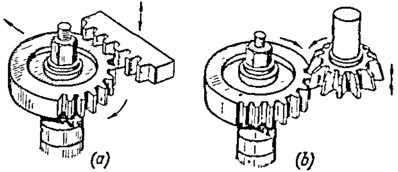


Fig. 255. Cutting gear teeth.
(a) with a rack-type cutter; (b) with a rotary gear shaper cutter

using a rotary cutter have found much wider application because they have a higher output (the cutting process is not interrupted to index the blank) and can perform all the operations done in hobbers, except for cutting worm wheels. They can additionally cut internal gears by the generating principle. The output of gear shapers is less than that of hobbers. They are indispensable, however, for such jobs as cutting internal gears of practically any diameter, as well as cluster gears in which the distance between the gear rims is not sufficient for the required overtravel of a hob.

A gear shaper (operating with the rotary-type cutter) has the following principal motions (Fig. 256). A. Straight-line primary cutting motion v_c accomplished by travel of the cutter only in one direction (cutting stroke) and return of the cutter to the initial position v_r (return stroke). B. Continuous rotation of the shaper cutter (v_1) and of the gear blank (v_2) to obtain the circular feed (indexing motion). The speeds of cutter and blank rotation are co-ordinated by means of change gears in such a manner that in one revolution of the cutter the blank makes $\frac{z_c}{z}$ revolutions, where z_c = number of teeth on the cutter and z = number of teeth on the gear to be cut. C. Feed-in motion s_{fi} (radial or circular infeed) of the cutter is obtained by travel of the cutter axis in a direction toward the blank axis with reciprocation of the cutter and circular feed. When the cutter has fed in to the required depth, i.e., to the whole depth of the teeth, the feed-in motion ceases automatically while the circular feed and the cutting motion continue until the gear blank makes one full revolution. This cuts all the teeth and the machine is automatically stopped. A gear can be cut in one, two or three passes. D. Withdrawal of the table with the blank from the cutter, or the cutter from the blank takes place during each return stroke. Its purpose

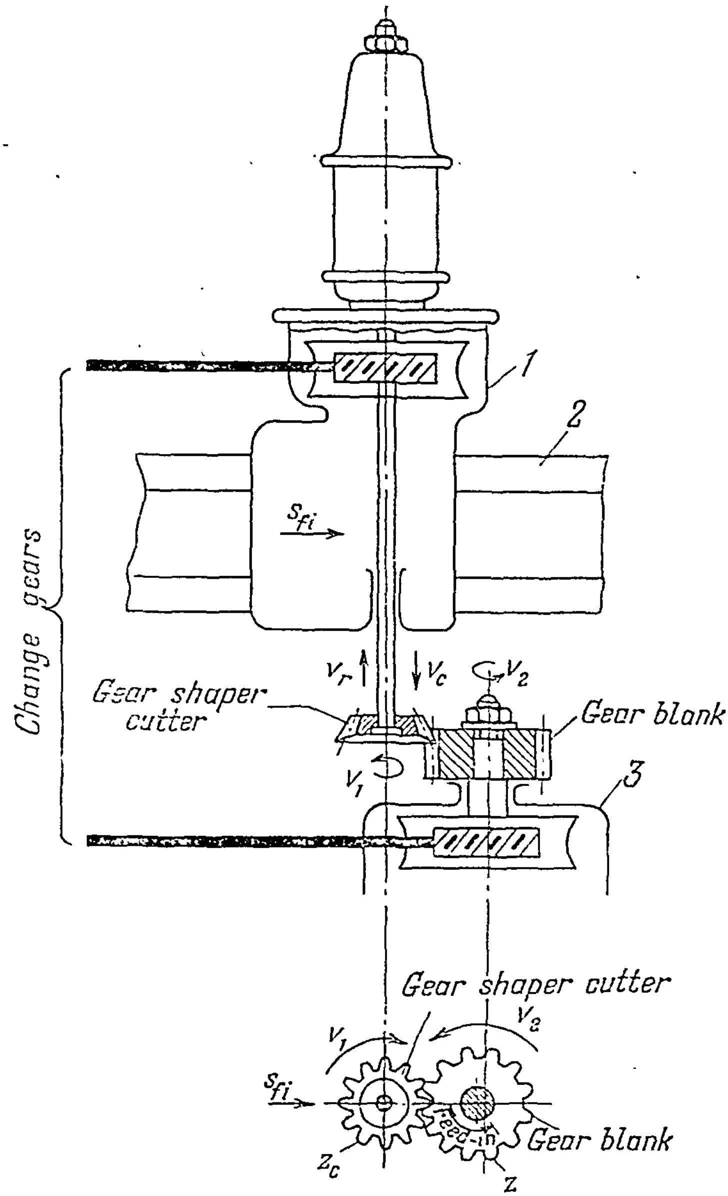


Fig. 256. Principle of the gear shaper:
1—saddle; 2—rail; 3—table

is to prevent rubbing and consequent intensive wear of the cutting edges and damage to the tooth profiles of the gear being cut.

In the medium-size gear shapers, the table with the blank is withdrawn from the cutter during the return stroke (Table 40). The withdrawing motion

21-0349

TABLE 40

Type of gear shaper	Model	Maximum diameter of blank, mm	Maximum module cut, mm	Number of full strokes of cutter per min	Power of drive motor, kW	Net weight, kg approx	Remarks
Operating with a single rotary cutter Automatic shaper	5107A	80	1	400 to 2,000	0.6	850	Cutter ram withdrawal on return stroke
Semiautomatic shapers	5M12	200	4	200 to 700	1 7	1,900	Table withdrawal on return stroke
	5140Б 5Б150П 5Б161П [illegible]	500 800 1,250 2,000	8 12 12 12	90 to 550 30 to 180 25 to 150 40 to 210	1.5-4.5 7.5 7.5 7.5	4,400 10,000 10,500 10,800	Cutter ram withdrawal on return stroke
Operating with a multiple-tool shaping cutter head	5A110 5A120 5A130	125 200 320	5 6 10	60 to 120 50 to 120 32 to 100	14 17 20	11,600 13,700 15,700	All the teeth of the gear are cut simultaneously

is imparted to the ram with the cutter in the heavier machines (models 5140Б, 5B150П, etc.).

Gear shapers are available with either vertical or horizontal spindles. The horizontal spindle shapers usually operate with two rotary shaping cutters travelling toward each other. They can be employed for external and internal spur and helical gears, as well as continuous-teeth herringbone gears (without a clearance gap).

The vertical type of gear shaper is more widely used. In addition to the machines using a rotary gear shaping cutter, operating on the generating principle, models are available which operate by the form-cutting process and use a multiple-tool shaping cutter head (see Fig. 247).

The output of this last type of gear-cutting machine is 8- to 10-fold that of ordinary gear shapers, and more than 4-fold the output of gear-hobbing machines. The most serious drawback of these machines is that a special complex cutter head must be available for each size of gear to be made (each module and number of teeth).

The kinematic chains of gear shapers is taken up in detail in Part Three, Vol. 2, Sec. 5-4.

13-6. Bevel Gear Generators

Bevel gears can be cut, as mentioned previously (see Sec. 8-3), in universal milling machines or shapers. However, the accuracy of bevel gears, cut by this method, is so low that such methods and machines can be employed only in extreme cases when no special gear-cutting machines for bevel gears are available. Moreover, the output of millers and shapers is very low when they are used for cutting bevel gears.

At the present time, bevel gears are manufactured both by the form cutting and generating processes. The form-cutting principle is used in cutting large bevel gears up to 5,000 mm in diameter and with a module up to 80 mm (Table 41) with a single tool or with two tools which operate to a template.

The generating principle is based on reproducing the sides of the teeth on an imaginary crown gear in space by means of the cutting edges of rotating cutters or reciprocating tools (Fig. 257). The profiles of the straight cutting edges coincide with the opposing sides of two teeth of the imaginary crown, or generating, gear with which the gear being cut is in mesh. The primary cutting motion, either rotation or reciprocation, is transmitted to these cutting edges. Motion of the first type (rotation) is accomplished in straight bevel gear generators designed for cutting bevel gears with a short face width. These generators use rotating circular cutters operating by the generating principle (for example, model 5230, see Table 41).

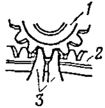


Fig. 257. Tools with straight cutting edges that form one tooth space of the imaginary crown gear

1—bevel gear blank, 2—imaginary crown gear, 3—tools

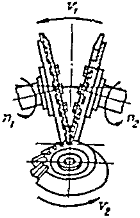


Fig 258. Generating a *straight bevel gear* with rotating circular cutters

The rotating cutters (Fig. 258) revolve about their axes to provide the cutting action (n_1 and n_2), travel in planes passing through the sides of the teeth on the *imaginary crown gear to shape the teeth along their length*, and at the same time they participate in the relative rolling motion between the cutters and blank to obtain the required tooth profile (v_1 and v_2).

Straight-line cutting is made use of in the straight bevel gear generators that have two reciprocating tools which shape the profiles of the teeth being cut. In a machine of this type, gear blank *1* (Fig. 259) is rotated (n_1 rpm). Also rotated is cradle *2* (n_2 rpm) with the reciprocating tools which represent kinematically the adjacent sides of a tooth in an imaginary crown gear.

Tool slides *3* with tools *4* reciprocate (v) along ways arranged on the face of cradle *2*. The tools cut in their motion toward the apex of the gear pitch cone. The tools do not cut on the return stroke, when they are withdrawn from the blank to avoid damaging the machined surfaces of the teeth

Figure 260 shows the successive positions of the tools and gear blank during generation. At the beginning of the tooth cutting process, the tool for machining one of the side surfaces of the teeth starts to cut into the blank (Fig. 260, positions *1* and *2*). Then the second tool, designed to shape the other side surfaces of the teeth, begins to cut the gear (Fig 260, positions *3* and *4*). At this point, the first tooth has been completely generated. Upon further rotation (roll) of the cradle the tools run out of mesh with the gear blank, since the two tools represent only one tooth space of the imaginary crown gear. Therefore, when the tooth has been shaped, both blank and

TABLE 41

Type of machine	Model	Maximum diameter of blank, mm	Maximum module cut, mm	Speed of tools or cutters	Power of drive motor, kW	Net weight, kg approx.	Remarks
				Full strokes per min			
Straight bevel gear generators	5T23B	125	1.5	up to 800	0.6	3,000	Operate with two reciprocating tools
	5A250П	500	8	75 to 472	3	8,000	
	5282П	800	16	30 to 307	7.5	12,000	
Template-type straight bevel gear planers	5A283	1,600	30	17 to 127	7.5	19,000	Operates with two tools
	52TM2	3,200	40	3.5 to 80	10	40,000	Operate with a single tool
	(5285)	5,000	80	3.5 to 15	14	50,000	
				m per min			
Spiral bevel gear planing generator	5A284	1,600	30	up to 80	17	35,000	Generates gear with a single tool. Blank indexes one tooth in full stroke of tool
Straight bevel gear generator	5230	320	8	27 to 180	3	7,000	Operates with two rotating cutters
Spiral bevel gear generators	5T23A	125	2	43 to 540	0.8	3,000	Operate with face-mill type cutters
	5T24A	250	6	200 to 500	3.5	5,000	
	527B	500	10	25 to 325	4.5	10,500	
	528П	800	15	21 to 300	10	14,000	

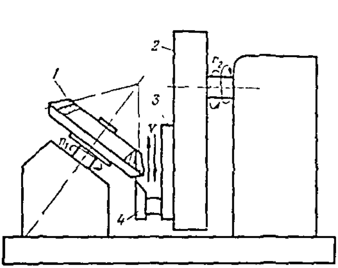


Fig. 259. Principle of the straight bevel gear generator

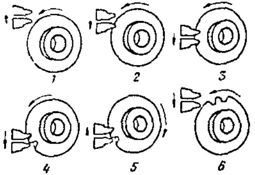


Fig. 260. Successive positions of the tool and the gear blank in generating a straight bevel gear

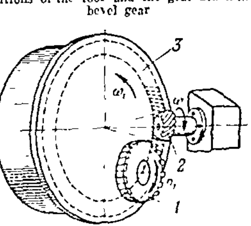


Fig. 261. Curved-tooth bevel gear being cut on a generating type machine

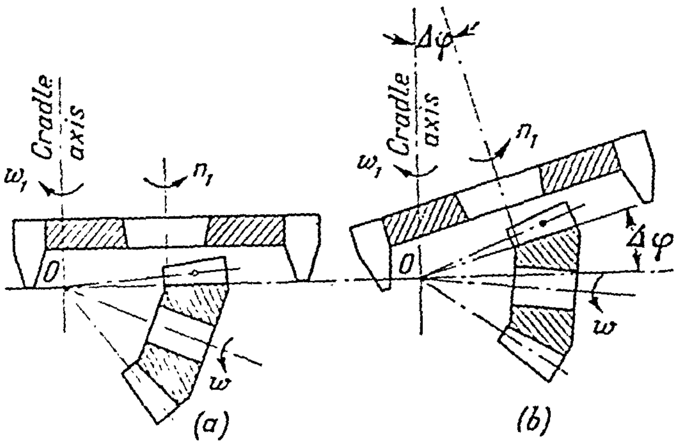


Fig. 262. Arrangements of the gear blank and the face-mill type cutter in relation to the cradle axis

cradle are reversed. At the end of this reverse rotation, the blank is indexed to the next tooth (Fig. 260, positions *5* and *6*). This procedure is repeated for each tooth of the gear in the same sequence. The two tools are not subjected to the same load in operation since one of them cuts into the blank for each tooth and wears faster than the other tool. To eliminate the effect of this nonuniform wear on the profile accuracy, the teeth are finish cut after roughing the tooth spaces. Most of the stock is removed in the roughing operation.

Roughing is done either with single indexing in which tooth spaces are cut in succession, or by continuous indexing to every other tooth. In the latter case, both tools operate under identical conditions.

Curved-tooth bevel gears of the spiral bevel, zerol and hypoid types are cut in machines using the face-mill type of cutters and operating on the generating principle (model 5T23A and others). In the cutting process, the gear being cut meshes with an imaginary crown, or generating, gear of which the active surface of the rotating cutter represents one tooth. The tooth form is obtained as a result of a relative rolling motion between the cutter and the blank.

Spiral bevel gear generators have the following principal motions (Fig. 261): (a) primary cutting motion due to independent rotation of cutter *1* (n_1 rpm); (b) roll motion consisting of rotation ω_1 of cradle *3* with the imaginary crown gear and rotation ω of gear blank *2* which is co-ordinated with cradle roll through change gears (not shown in the diagram); (c) withdrawal of the blank from the cutter after cutting each tooth; and (d) indexing

motion which is transmitted to the blank when the cradle returns to its initial position after cutting each tooth.

Curved-tooth bevel gears may be cut either with the aid of a crown gear, in which case the axis of the cutter is parallel to the cradle axis as in Fig. 262*a* (model 5T23A), or with a bevel generating gear (Fig. 262*b*). In the latter case, the blank and the cutter can be swivelled through an angle $\Delta\varphi$ in reference to the plane of rotation of the cradle (this principle is applied, for example, in model 527B).

The kinematic principles involved in cutting bevel gears and the gearing diagrams of the machines used for this purpose will be considered in Part Three, Vol. 2, Sec. 5-6.

13-7. Gear-Finishing Machines

In the great majority of cases, the teeth of machined gears undergo a finishing operation since after cutting the gear the surface finish on the tooth profiles or the meshing errors do not comply with the requirements specified for the gears. Gear-finishing methods include: burnishing, shaving, lapping, grinding and honing.

Gear burnishing. As the result of plastic deformation of the surface layer of metal, the side surfaces of the teeth of unhardened gears are compressed by burnishing. This operation consists essentially in rolling the work gear with one or several burnishing gears whose teeth are very hard, smooth and accurate. The latter gears are driven by a motor. The required load is applied by a weight or by means of electric, pneumatic or hydraulic devices.

The capacity of a gear-burnishing machine is specified by the maximum diameter of gear it accommodates. The capacity of gear-burnishing machines produced in the Soviet Union ranges from 125 to 5,000 mm (Table 42).

Gear shaving is based on the cutting of fine chips from 0.005 to 0.1 mm thick from the gear-tooth profiles by the cutting edges of the tool during the relative sliding motion of the tooth profiles on the meshing work gear and tool. The latter is called the gear-shaving cutter. The forms of the cutter correspond to the two methods of shaving, rotary and linear (rack). The rotary method employs a gearlike cutter, the rack method uses a cutting tool having the shape of a rack and is employed to a lesser extent than the first method. The cutter teeth are serrated to form a series of cutting edges (Fig. 263). To obtain the relative sliding action between the tooth profiles, the work gear and the shaving cutter are set up in the gear-shaving machine with crossed axes in the form of spiral gearing. The most efficient angles between the axes are between 10° and 15°. The least permissible angle is 5° which is used in shaving gears having a flange or shoulder that interferes with the cutter at a larger angle.

TABLE 42

Model	Maximum diameter of gear burnished, mm	Speed of rotation, rpm	Power of drive motor, kW	Net weight, kg approx.	Remarks
5A720	125	850 to 10,000	1	1,100	Universal
5722	250	400 to 4,000	1.7-3	2,000	
5A725	500	625 to 1,250	2/3	3,100	
5B726	800	230 to 1,250	5/7	4,400	
5727	1,600	180 to 810	6.5/10	7,500	
5728	3,200	60 to 600	19	22,000	
(5729)	5,000	20 to 200	40	40,000	
5B725	500	400 to 4,000	7	3,000	For bevel gears with a 90° shaft angle

The tooth profile of the work gear is sized at the crossed-axes pivot point which is on the line of the shortest distance between the cutter and gear axes. It is necessary to reciprocate the work gear or the cutter in order to move the pivot point from one end of the gear face to the other so that the whole face width is machined. There are several methods of moving the pivot point of the shaving cutter across the work gear in rotary crossed-axes shaving: axial traverse, angular traverse, right-angle traverse and modified tangential shaving. Angular traverse shaving and right-angle traverse shaving were formerly called diagonal and tangential shaving, respectively.

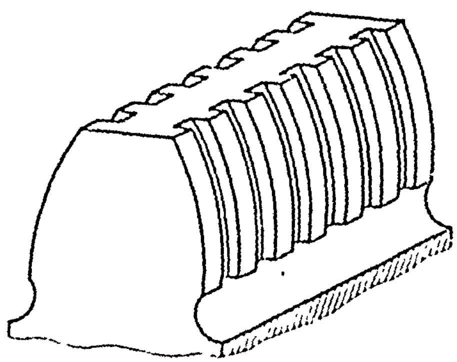


Fig. 263. Tooth of a gear-shaving cutter

In axial traverse shaving (Fig. 264*a*) the work gear is reciprocated at the rate of traverse s, in mesh with the cutter, along a path parallel to the work-gear axis. The length of the stroke L_1 is theoretically equal to the face width of the gear. In this case, the pivot point remains stationary in reference to the cutter and thus generation is performed by the same cutting edges passing through the pivot point or, more

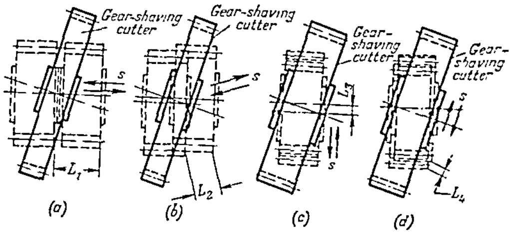


Fig 264. Methods of rotary crossed-axes shaving
(a) axial traverse, (b) angular traverse, (c) right-angle traverse, (d) modified tangential

exactly, through the area of contact. This leads to nonuniform wear of the cutting edges.

In angular traverse shaving at the rate s (Fig. 264*b*), the required stroke L_2 is shorter since the work is fed at an angle relative to its axis. Moreover, the pivot point, or point of intersection, where cutting action occurs, moves progressively across the face of the cutter on every stroke. Thus wear is distributed over the entire cutter face, and cutter life is increased.

In right-angle traverse shaving (Fig 264*c*), the cutter is reciprocated at the rate s across the axis of the work gear at 90°. The required stroke L_3 is even less than in the angular traverse method and cutter wear is uniform over all the cutting edges.

What we have called modified tangential shaving (Fig. 264*d*) differs from the right-angle traverse method in that reciprocation at the rate s is perpendicular to the cutter axis and not to the work-gear axis. The required stroke L_4 is the shortest in this case.

The surface finish of teeth shaved by the right-angle traverse and modified tangential methods is improved, the friction forces are stabilized in the shaving process and the process is intensified by imparting an oscillatory motion with a frequency of 20 to 100 cps, in the plane of cutting, to either the work gear or the cutter. This oscillatory motion in the cutting plane when applied in modified tangential shaving, improves cutting conditions and allows the work to be shaved in a single pass with no adverse effect on the surface finish This means that the machining time can be reduced to $^1/_8$ or $^1/_{10}$ of that required in axial traverse shaving

TABLE 43

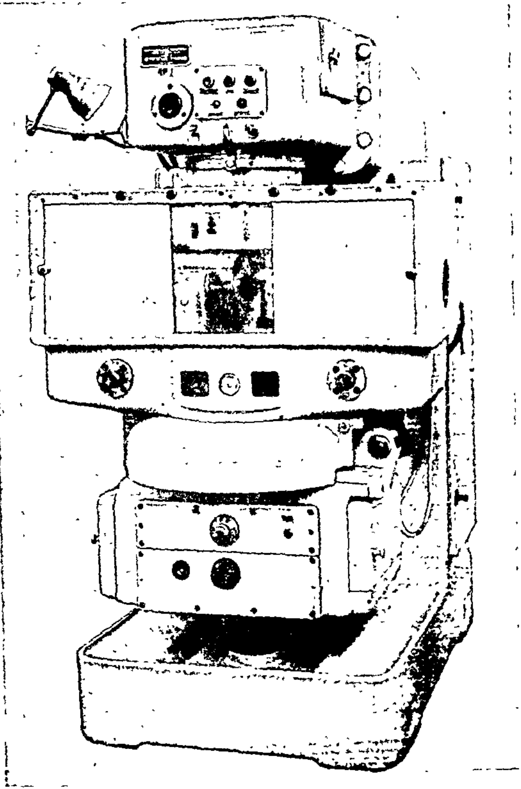
Model	Maximum diameter of gear shaved, mm	Maximum module shaved, mm	Range of work speeds, rpm	Power of drive motor, kW	Net weight, kg approx.	Remarks
5701	125	1.5	80 to 500	1.6	1,500	Operates by: axial traverse
5702A	200	6	78 to 395	2.8	3,400	axial, angular and right-angle traverse
5A702	320	6	80 to 315	3	3,000	axial and angular traverse
5703B	500	8	78 to 395	3.5	3,400	
(5717C-1)	800	10	50 to 320	4.5	10,000	With horizontal work gear and cutter axes
5706	1,250	16	16 to 227	13.5	30,000	
5708	3,200	16	4.8 to 51	14	54,000	

The main dimensions of gear-shaving machines are the maximum diameter and module of gear shaved. Soviet machine tool plants manufacture gear shavers for gears up to 3,200 mm in diameter (Table 43).

The model 5702 gear-shaving machine is illustrated in Fig. 265; its combined hydraulic circuit and gearing diagram is shown in Fig. 266.

The shaving cutter has 10 steps of speed in the range from 49 to 389 rpm, obtained by change gears. The change gears in the axial traverse drive provide for 13 rates of traverse in the range from 17.6 to 273 mm per min. Radial infeed is accomplished by vertical travel of the table knee. Shaving cutter rotation and axial traverse are powered from an electromechanical drive; radial infeed is hydraulically operated.

The machine operates as follows. When the drive motor of pump P is switched on, solenoid Sd_3 of valve V_2 is energized and oil from the pump is delivered through filter *1*, reducing valve *2*, valve V_2 in its left-hand position and valve V_1 in its right-hand position to the rod end of the tailstock spindle cylinder. This retracts the tailstock spindle. After loading the next work gear, the spool of valve V_1 is shifted by hand to the left position to advance the tailstock spindle again. At the end of its travel this spindle operates limit switch LS_5 which energizes solenoid Sd_5 of valve V_3 and de-



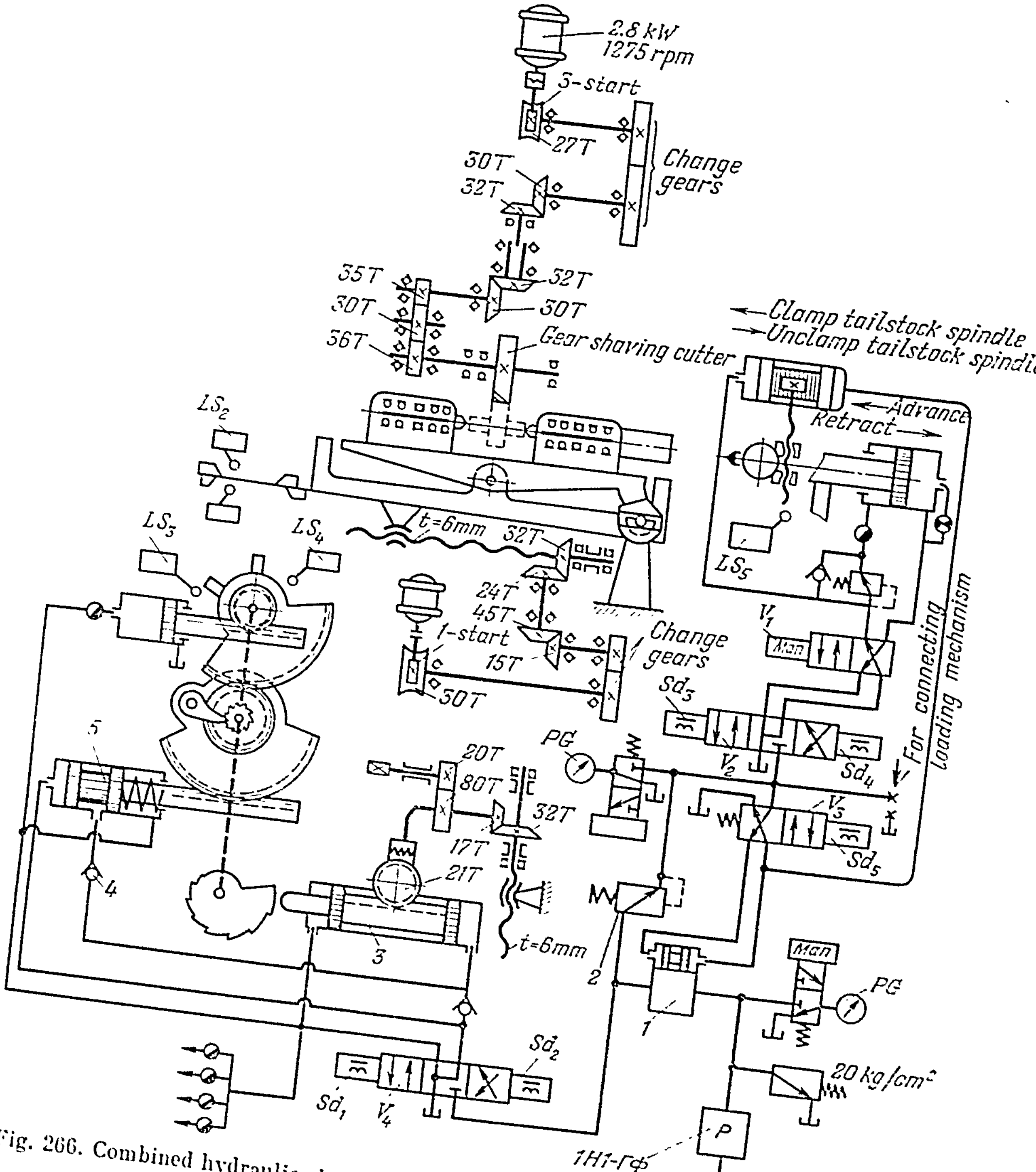


Fig. 266. Combined hydraulic circuit and gearing diagram of the model 5702 gear-shaving machine

energizes solenoid Sd_3, through a time-delay relay. Pressing the START push button switches on the drives of the shaving cutter, table and coolant pump, and also energizes solenoid Sd_1 of valve V_4 as well as its time-delay relay. Oil from the pump passes through filter *1* and valve V_4 in its *left-hand position*. After shifting the piston of cylinder *5* to the right and turning the driving element of the pawl, this oil passes through check valve *4* into infeed cylinder *3*. This leads to rapid approach of the table knee. After a period of time, equal to the time required for rapid approach of the knee and for one infeed motion, the time-delay relay de-energizes solenoid Sd_1. The action of a spring returns the piston of the cylinder to the initial position. At the end of the table stroke in either direction, limit switch LS_2 reverses the cutter rotation and table traverse drives, and energizes solenoid Sd_1 and its time-delay relay. This effects the infeed motion. At the beginning of the last sizing pass, limit switches LS_4 and LS_2 (in the right-hand position of the table) switch off the drives of the cutter, table and coolant pump, energize solenoid Sd_2 of valve V_4 and de-energize solenoid Sd_3

At this, the table knee and the infeed cam return to their initial positions. At the end of cam return, limit switch LS_3 energizes Sd_3. Now, when the spool of valve V_1 is shifted to the right, the tailstock spindle is retracted to allow the work to be unloaded.

Gear lapping is employed for finishing the profiles of hardened gear teeth by an abrasive action, running the work gear together with the lapping gear (the cutting tool) and using a fine abrasive powder in suspension in kerosene or light oil. The lapping gear is a precisely manufactured fine-grain cast-iron gear. The relative motion in gear lapping is the same as in gear shaving. Gear-lapping machines differ from gear shavers in that they do not have an infeed drive, as a rule, since the lapping allowances are very small. The required pressure at the places of contact between the work and lapping gears is obtained by the provision of a brake, usually hydraulic, in the headstock of the gear-lapping machine This brake is a pump which is driven by the work gear arbor and is loaded by means of a throttle or overflow valve.

Dimensions specifying the capacity of gear-lapping machines are the maximum diameter and module of gears lapped (or the centre-to-centre distance for machines designed to lap globoid worm gearing) Rotation is imparted to the lapping gear in all gear-lapping machines, while the reciprocating motion may be transmitted either to the work gear or the lapping gear (Table 44)

Gears with a high degree of accuracy and with precise meshing of the tooth profiles can be produced by the lapping process One drawback of gear lapping is the comparatively low output

Gear grinding is an indispensable operation for eliminating the distortion of gear tooth profiles due to heat treatment It produces gears of especially

TABLE 44

Type of machine	Model	Maximum diameter of gear accommodated, mm	Range of main drive speeds, rpm	Available power, kW	Net weight, kg approx.
Universal bevel-gear lapping machines	5П720	125	300 to 3,000	1	1,400
Bevel-gear lapping machine (90° shaft angle)	5У725	500	700 to 1,300	3/4.5	4,500
Spiral-bevel-gear lapping machine	5П725	500	1,300	3	3,600
Bevel-gear work-hardening machine	5724	800	450 to 900	10/14	7,000
	5П725	500	1,300	3	3,000
Spur- and helical-gear work-hardening machine	5723	320 (module up to 6 mm)	200 to 500	7	1,400

high accuracy (3rd, 4th and 5th grades of accuracy according to USSR Std GOST 1643-56) and with a fine surface finish on the tooth profiles.

The disadvantages of this process are the low production capacity, dimensional instability in grinding, and the necessity of employing complex and expensive gear grinders tended by highly skilled operators.

Similar to gear cutting, gear grinding is done by two general methods: ormed-wheel grinding and generation grinding.

In grinding gears by the formed-wheel method (Fig. 267*a*), the periphery the grinding wheel is trued by three diamonds so that its profile in a radial ction coincides with that of the tooth space of the gear being ground. The nding wheel has a rotary motion v; it is reciprocated along the tooth and a periodic infeed s_z after each full stroke (back and forth along the gear th).

his method can also be used to grind internal gears.

he grinding wheel in generation gear grinding represents the profile e or several teeth of the basic rack and the grinding process is basec the relative motions of a meshing rack and gear (Fig. 267*b* and *c*) or shing worm and worm wheel (Fig. 267*d*).

ved-tooth bevel gears are ground by an end-type wheel trued to a proich, in the same manner as the blades of the face-mill type of cutter, nts a tooth of the imaginary crown gear or a bevel generating gear, ing upon the type of generating gear used to cut the gear (see Fig. 262). spect to their construction and methods of operation, a great variety grinders are available. Table 45 lists the main specifications of gear

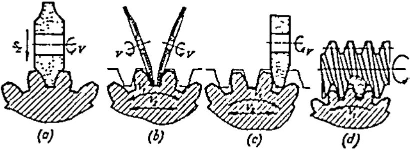


Fig. 267. Gear-grinding methods

grinding machines produced in the USSR at the present time. The kinematic features of gear grinders are considered in Vol. 2, Part Three, Sec. 5-5.

Gear-tooth honing is a new, highly productive procedure applied for finishing gears following gear shaving and heat treatment. The process eliminates small defects of the surfaces of hardened teeth, removes scale, nicks and burrs, and substantially improves the finish of the tooth surfaces (the height of surface irregularities is within 0.25 micron). The noise of gearing after heat treatment can be considerably reduced by honing.

Gear-tooth hones, used in this process, are essentially abrasive-impregnated, plastic helical gear-shaped tools. The grain size of the abrasive (40, 60 or 80) is selected in accordance with the grade of steel of the work gear, and the hardness and required finish of the tooth surfaces.

The relative motions in gear-tooth honing are the same as in gear shaving. Gear-tooth honing machines are similar in construction to gear shavers and can operate either with a constant distance between the axes of the gear-tooth hone and work gear, or with a constant pressure between them (the spreading force is about 13 to 15 kg).

Gear-tooth honing is carried out at a peripheral speed of the hone twice that of a shaving cutter. The amount of stock removed from each tooth profile in honing does not exceed 10 microns.

The teeth being honed may be crowned or tapered providing that this shape has been produced in the preceding shaving operation.

13-8. Gear-Tooth Rounding, Chamfering and Deburring Machines

Sliding gears that are shifted axially into engagement are made use of in gearboxes of various mechanisms and machines. The ends of the teeth of sliding gears should be rounded to facilitate shifting them into mesh.

TABLE 45

Machines for grinding	Model	Maximum diameter of gear ground, mm	Maximum module ground, mm	Wheel speeds, m per sec	Available power, kW	Net weight, kg approx.	Remarks
Spur and helical gears	5B832 5B833 5B835 (58 8)	200 320 500 800	3 4 6 8	30 to 35 30 to 35 30 to 35 30 to 35	3 5.5 5.5 10	6,800 7,200 10,000 12,000	Semiautomatic with helically profiled wheel
Gear-shaping and shaving cutters, master gears	5891 5A893	125 320	6 16	30 30	0.6 1.1	2,000 4,000	Generating principle with involute cams; indexing with a master plate
Spur and helical gears	5841 5842 5843 5844	320 500 800 1,250	6 10 12 16	30 30 30 30	0.6 1 1.7 1.4×2	4,100 6,000 8,300 12,000	High-precision generation grinding with a taper wheel
Spur and helical gears	5851 5852 5853	320 500 800	10 12 12	30 30 30	0.6×2 0.6×2 0.6×2	5,500 7,000 8,500	Extra-high precision generation grinding with two saucer-shaped wheels. Horizontal arrangement

Turbine gears (pinion shafts)	5858	3,200	20	30	4.5	30,000	Extra-high precision with two saucer-shaped wheels
Internal spur gears	586B 5B860	500 600	10 8	30 30	7.5 10	8,500 9,700	Formed-wheel grinding with single indexing. Horizontal work axis
External spur gears	586 5860B 5868	500 800 1,250	10 12 16	30 30 35	7.5 11 8	8,500 9,700 19,500	
Straight bevel gears	5870B 5A871	250 500	8 10	up to 30 up to 35	1.1 1.1	7,500 12,200	Generation grinding with two wheels
Spiral bevel gears	5A870B 5871 5A872	250 500 800	8 10 15	up to 35 up to 35 20 to 50	3 4.5 4.5	7,500 10,500 12,500	Generation grinding principle

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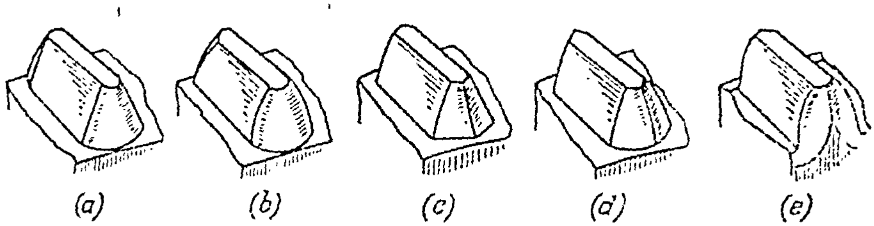


Fig. 268. Shapes of the rounded tooth ends on sliding gears:
(a) tapered; (b) barrel-shaped; (c), (d) and (e) concave, convex and partly pointed

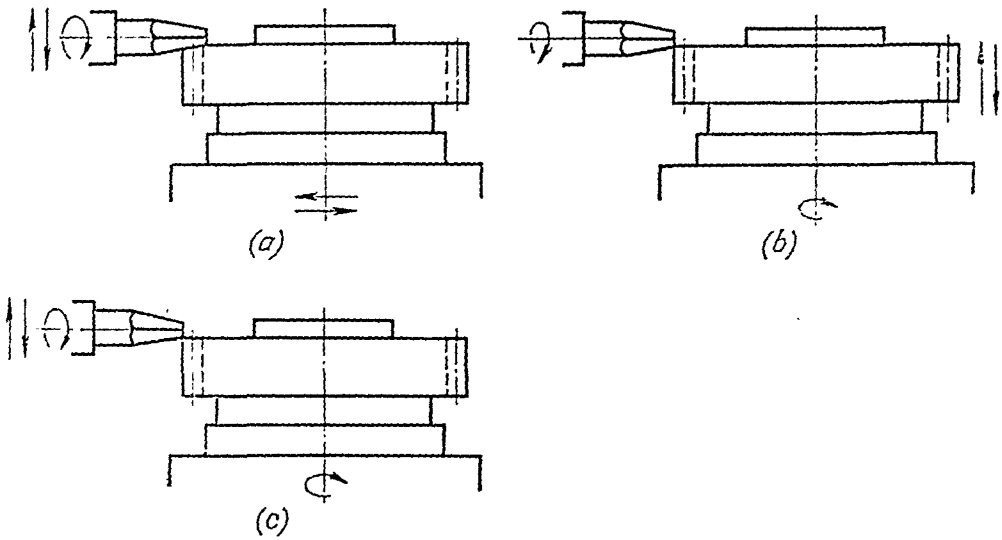


Fig. 269. Methods of rounding ends of gear teeth with an end-mill type cutter whose axis is in a plane parallel to the end face of the gear

The rounding of the teeth of sliding gears, as well as tooth chamfering and deburring, can be done by various methods: (a) with an end-mill type cutter whose axis of rotation is either parallel or perpendicular to the end face of the gear; (b) with bell-type formed cutters; (c) with a cutter head; (d) with a formed hob; (e) with an arbor-type formed cutter; and (f) with an abrasive tool. Applying these methods, the gear teeth are rounded to the shapes illustrated in Fig. 268. Barrel-shaped tooth ends (Fig. 268*b*) provide maximum service life of the sliding gears, in conjunction with easy and smooth engagement in shifting. This type of tooth rounding is produced with an end-mill type formed cutter having its axis parallel to the end face of the gear, or with an arbor-type formed cutter.

The most extensively used machines of this type operate with continuous indexing and a synchronous reciprocating motion of an end-mill type cutter along the axis of the work gear (Fig. 269*a*). The reciprocating motion is

TABLE 46

Type of machine	Model	Maximum diameter of gear machined, mm	Maximum module machined, mm	Range of speeds of primary cutting motion, rpm	Power of drive motor, kW	Net weight, kg approx.
Gear-tooth rounding machines:						
automatic with end-mill type cutter	5H580	320	6	1,500 to 2,800	1.5	2,500
with end-mill type cutter	5582 5584	500 800	8 12	1,000, 1,600, 2,500, 750, 1,000, 1,500, 2,500	1.7 1.7	2,700 3,000
semiautomatic with arbor-type formed cutter	5B580	320	6	140 to 580	2.2	2,800
Semiautomatic gear-tooth deburring machine using an abrasive worm-type wheel	5524	320		2,000 to 3,200 (wheel speed)	1	1,600
Semiautomatic gear-tooth chamfering machines using an abrasive disk	5525 5527	500 1,500	10 16	8,000 to 10,000 and 0.5 to 5, 8,000 and 0.3 to 1.5	0.3 0.5	300 800

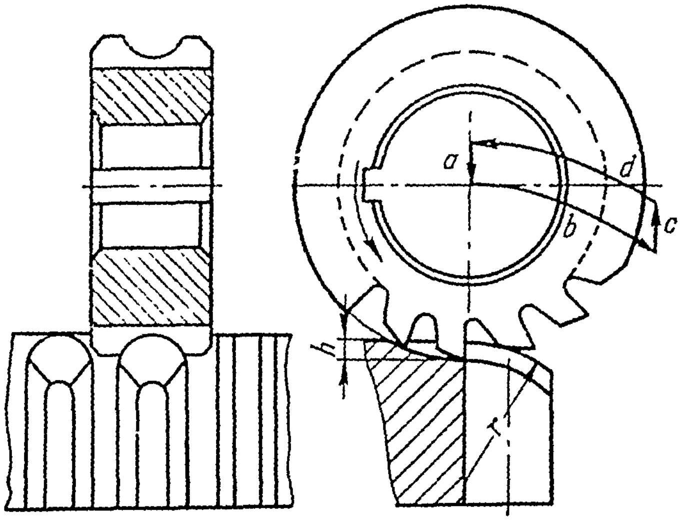


Fig. 270. Rounding the tooth ends with an arbor-type formed cutter

effected by a template. Soviet models 5H580, 5582 and 5584 (Table 46) are designed along these lines. In some models the work gear reciprocates axially (Fig. 269*b*) instead of the cutter, while in others the work gear indexes periodically from tooth to tooth, and the cutter rotates and oscillates around the end of the tooth (Fig. 269*c*). The gear is indexed in the latter type of machine with the work table withdrawn.

Tooth rounding with an end-mill type cutter has the following drawbacks: (a) low tool life and high labour input in manufacturing and sharpening cutters with a concave profile; (b) the formation of needlelike chips, difficult to dispose of and hazardous to the operator's hands; and (c) low production capacity.

A new method of producing barrel-shaped tooth ends with an arbor-type formed cutter was developed in ENIMS (Experimental Research Institute for Metal-Cutting Machine Tools). The output of this method is 3- to 6-fold that of the methods in which an end-mill type cutter is used and a fine surface finish is obtained. Furthermore, due to the changes in the shape of the cutting tool and in the cutting process, the formation of needlelike chips is excluded. In the new method, the cutter axis is in a plane parallel to the end face of the gear and perpendicular to a radial plane.

The machining cycle for each tooth comprises the following motions: (1) feed-in of the cutter on the end face of the gear to the full depth to be rounded (section *a* in Fig. 270); (2) milling the end surface along the height of the tooth with the radius *r*, accomplished by motion of the cutter axis along arc *b*; (3) rapid withdrawal of the cutter from the work gear (section *c*);

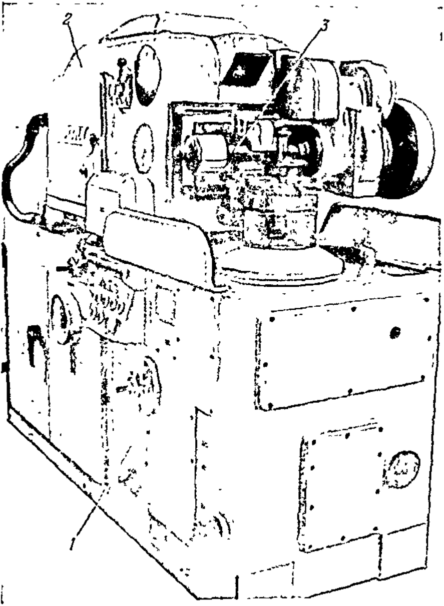


Fig. 271. Semiautomatic gear-tooth rounding machine, model 5Б580

1—bed *2*—milling head *3*—cutter spindle

and (4) return of the cutter along arc d' to the initial position with simultaneous indexing of the gear to the next tooth.

The *semiautomatic gear-tooth rounding machine*, model 5Б580, shown in Fig. 271, operates with such a cycle. Milling head *2* travels along the horizontal V-ways of bed *1*. Mounted in the milling head are cutter spindle *3* with the mechanism for changing the cutter speeds, as well as a system of levers and cams that provide the required path of cutter travel along the height of the tooth of the work gear and the indexing mechanism which indexes the work gear from tooth to tooth.

Abrasive machining methods have been finding wide application recently for gear-tooth chamfering and deburring. The cutting tools used in this case are either worm-type grinding wheels or composite wheels made of sheets of abrasive cloth. A helical groove of a pitch equal to that of the gear being deburred, or annular grooves with the same pitch are provided on the periphery of the composite wheel.

In the machines using a worm-type wheel, the work gear is driven by the wheel and is mounted on a spindle which is not linked kinematically with the main drive.

Gear-tooth deburring machines with an abrasive cloth wheel may have either co-ordinated work gear and wheel rotation, i.e., the gear turns through one tooth upon each revolution of the wheel (if the wheel has a helical groove on its periphery), or independent rotation (if the wheel has annular grooves). In the latter case, a reciprocating motion is imparted to the wheel in addition to rotation to withdraw it from the gear during indexing.

CHAPTER 14
ELECTROMACHINING EQUIPMENT

Electromachining equipment, including electrical-discharge, electrolytically assisted and ultrasonic machining equipment, is intended for machining workpieces of cemented carbides, high-temperature (heat-resisting) alloys, super-hard and brittle materials, and other materials that are not machinable by ordinary cutting tools, as well as materials for which deformation due to the cutting force cannot be permitted. It is either extremely difficult or entirely impossible to shape such materials in conventional machine tools.

Electromachining equipment is employed in the manufacture of complex dies, plastics moulds, wire-drawing dies, as well as slots and holes of various shapes and of a size from several hundredths to several tenths of a millimetre.

14-1. Electrical-Discharge and Electrolytically Assisted Machining Equipment

Electrical-discharge machining is based on the disintegration of current-conducting materials (electrodes) by an electrical discharge occurring between them. Electrical-discharge machining, also known as spark erosion, was first proposed in the Soviet Union in 1943 and is now widely applied in all countries in the manufacture of machinery, instruments and apparatus.

Electrical-discharge machining of metals consists in the following. At each electrical discharge, a focused stream of electrons, flowing at a high velocity from one electrode to the other, produces compression shock waves on the surfaces of the electrodes. The pressure of the waves is many times more than the ultimate strength of the electrodes. The formation of the compression shock wave is accompanied by a local increase in temperature and a certain deformation of the surface layer.

The mechanical stress occurring in the metal spreads at a definite velocity in all directions, including the one from which the shock wave was propagated. When it reaches the initial surface and is reflected from it, the shock wave undergoes a reversal in sign, i.e., a tensile stress is developed in the surface layer of a magnitude that is many times more than the tensile

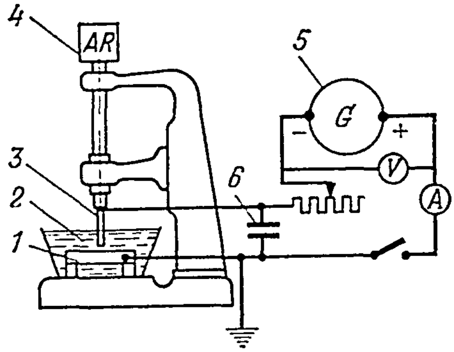


Fig. 272. Principle of spark-over-initiated discharge machining:

1—workpiece; 2—tank with dielectric; 3—tool or electrode; 4—automatic regulator of the spark gap; 5—d-c generator; 6—bank of condensers

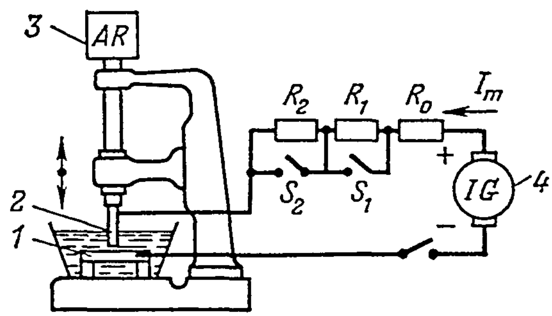


Fig. 273. Principle of electrical-pulse discharge machining:

1—workpiece; 2—tool or electrode; 3—automatic regulator; 4—impulse generator; R_0, R_1 and R_2—stages of current-limiting resistance; S_1 and S_2—stage selector switches

strength of the material. As a result, particles of metal are thrown out in the direction facing the compression shock wave.

There are four general types of electrical-discharge and electrolytically assisted machining equipment. Maximum efficiency of these machines is achieved in the corresponding fields of their application.

Spark-over-initiated discharge (*electrospark*) *machining* is used chiefly to pierce small-diameter holes, to make narrow slits and to make small parts of complex shape from materials difficult to machine. The output of this equipment is comparatively low (Table 47).

Relaxation generators are employed in this equipment to originate electrical impulses. In these generators the energy of the supply source is converted into oscillatory energy by means of an accumulating element which consists, in most cases, of capacitance (Fig. 272). In this equipment, the workpiece is the anode and the tool or electrode is the cathode. The tool can be made, for example, of soft brass. Machining is carried out in a non-conducting liquid medium, or dielectric (kerosene or industrial oils) which separates the workpiece and tool. The required spark gap between the workpiece and tool is maintained by a suitable servomechanism, called an automatic regulator.

Electrical-pulse discharge (*arc-erosion*) *machining* has a much higher output (Table 47) and is employed in machining medium- and large-size dies, plastics moulds, etc., and in machining hardened workpieces or low-machinability steels and alloys. This process can also be used in place of tracer-controlled milling in machining complex shapes.

The impulse discharges in this equipment are originated by a motor-generator, vacuum-tube or semiconductor generator which produces uni-

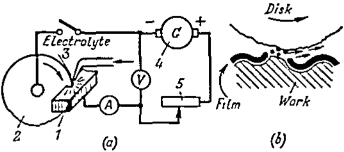


Fig. 274. Principle of electrolytically assisted machining (*a*); rupture of the film and discharge between the peaks of surface irregularities and the disk (*b*):
1—workpiece, *2*—tool; *3*—electrolyte; *4*—d-c generator; *5*—rheostat

polar current pulses of constant frequency (Fig. 273). In these machines, in contrast to the spark-over-initiated type, the workpiece is connected to the cathode and the tool to the anode. Either the workpiece or the tool is vibrated in the direction of the feed motion. The tool (electrode) can be made of copper, aluminium or cast iron. The most wear-resistant tools, however, are made of graphite carbon materials (grades Н9 and В1). Machining is carried out in a dielectric fluid.

Electrolytically assisted discharge machining is used to sharpen cemented-carbide tools, as well as for grinding, honing and cutting off difficult-to-machine materials. In this equipment, the workpiece is connected to the anode and the tool to the cathode (Fig. 274*a*). The machining is done in a current-conducting liquid medium, the electrolyte. The electrolyte, delivered into the gap between the tool and workpiece, dissolves the metal under the action of the current, and forms a thin film of oxides or salts on its surface (Fig. 274*b*). This weakly bonded film is easily removed by the tool, to which both the primary cutting and feed motions are imparted. A new film is formed in place of the removed one and this is also removed upon further motion of the tool. The electrochemical process is accompanied by electrical-discharge metal removal since spark gaps, through which discharges pass, occur when the film is removed.

Electrolytically assisted cutting-off machines employ a thin disk, or an endless band or wire made of soft steel, as the tool. The tool-sharpening machines use a sharpening disk made of steel, cast iron (including chilled iron) or soft copper. Microfinishing machines operating on this principle use current-conducting grinding wheels, abrasive sticks and laps.

The output of electrolytically assisted machining equipment and the surface finish obtained by this process depend upon the type of electrolyte used, and the electrical and mechanical data characterizing the process.

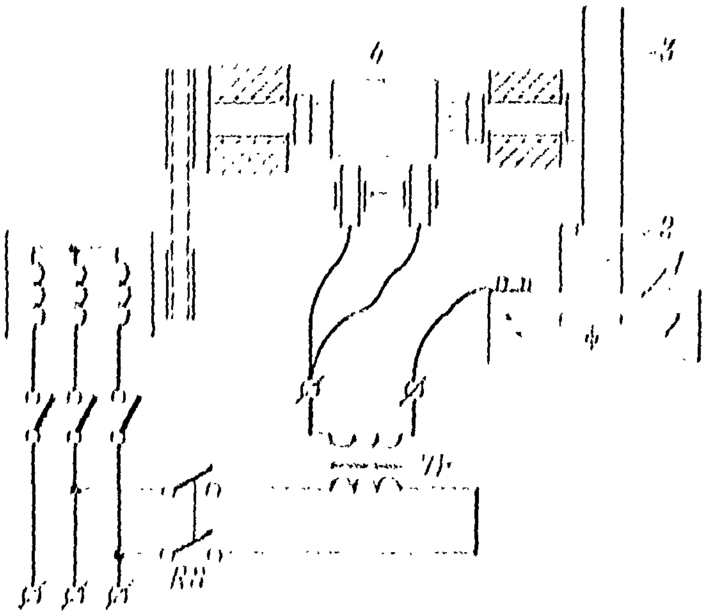


Fig. 276. Principle of contact initiated discharge machining:
1 — table; 2 — workpiece; 3 — disk; 4 — current collector; Tr — transformer; RS — rotary switch

Contact initiated discharge machining equipment (Fig. 276) is employed for roughing ingots and removing the skin on castings, for removing large amounts of stock from blanks and for cutting stock apart. In this equipment the metal is removed by a combination of contact, contact-arc and arc heating, as well as mechanical abrasion and removal of the softened metal from the surface of the workpiece with a tool. Both the primary cutting and feed motions are imparted to the tool, as in electrolytically assisted machining equipment. Contact between the tool and workpiece may be either continuous or instantaneous; its purpose is to initiate the electrical discharge.

The efficiency of the process is not affected by the polarity of the electrodes when it is conducted in air. This allows a low voltage (2 to 30 V) alternating current supply to be used with a high current intensity (800 to 1,000 A, and sometimes up to 8,000 A).

The polarity effect appears when the workpiece is machined in a liquid medium so that a direct current is used in this case. Machines of this type have much in common with spark over initiated discharge and electrolytically assisted machining equipment.

14-2. Ultrasonic Machining Equipment

Ultrasonic machine tools (Fig. 276*a*) differ from electrical-discharge equipment that can machine only current-conducting materials in that nonconducting materials can also be readily machined. These include such brittle and hard materials as glass, ceramics, porcelain, quartz, germanium, silicon, rubies, diamonds, cemented carbides, hardened steel, etc.

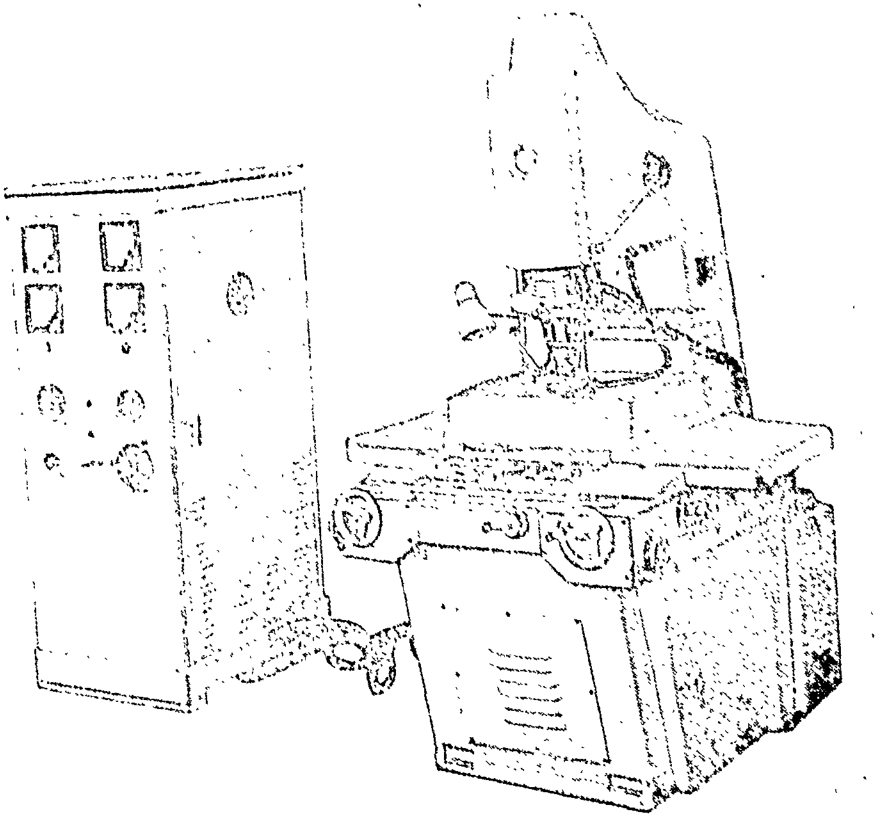
Ultrasonic machining has much in common with electrical-discharge machining. The compression shock waves occurring on the surface of the workpiece in ultrasonic machining are due to the impacts of the abrasive grains. The large number of grains striking the surface simultaneously (30 to 100 thousand per sq cm) and the high frequency of impacts (16 to 25 kcps) provide a metal removal rate that is acceptable for practical purposes.

Motion is transmitted to the abrasive grains by the vibrating end of tool *2* (Fig. 276*b*) which is connected through toolholder *3* to magnetostrictive transducer *4*. The transducer consists of a stack of plates made of a magnetostrictive material, i.e., one having the property of changing its physical dimensions upon changes in the magnetic field. The transducer coil is supplied by current at a frequency of 16 to 25 kcps from an ultrasonic generator. This current is converted by the transducer into mechanical vibrations of the same frequency. The vibrating system is mounted on spindle *5* which can travel vertically on the ways of column *6* and applies the tool to the surface of workpiece *1* with a definite force.

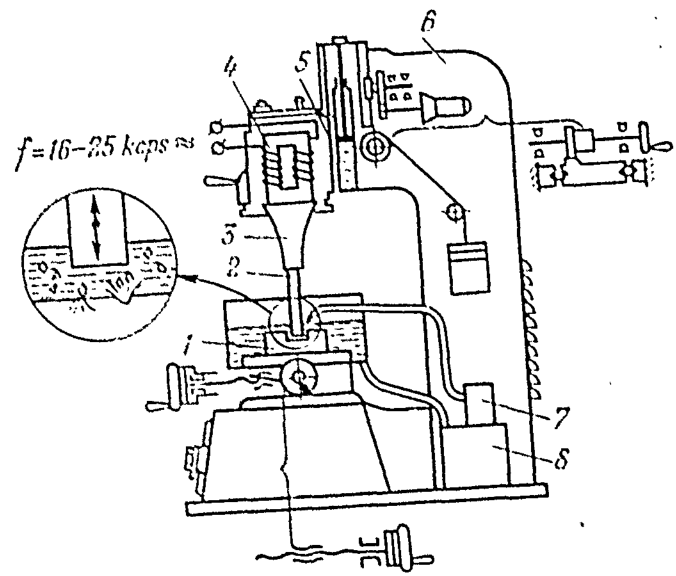
Ultrasonic machining is most intensive when the workpiece is submerged in a liquid medium. Cavitation phenomena in the liquid promote intensive mixing of the abrasive grains under the tool and the substitution of new grains for fractured or worn ones. For this purpose, pump *7* delivers a slurry of water and fine abrasive from tank *8* to the machining zone.

Materials with a comparatively low tensile strength, such as glass, ceramics, etc., can be most readily machined by this process. It is considerably more difficult to machine stronger materials, such as cemented carbides. Plastic materials with a sufficiently high tensile strength are not machined ultrasonically to any appreciable extent. This is due to the comparatively small energy of the abrasive grains striking the workpiece surface.

In addition to the electromachining processes discussed in this chapter, a number of other new techniques have been proposed but are still in a stage of experimental research. S
machining metals with high-
with focussed electron and light beams, etc.



(a)



(b)

Fig. 276. Ultrasonic machine tool, model 4773 (a) and principle of ultrasonic machining (b)

PART TWO

MACHINE TOOLS FOR CUTTING TOOL PRODUCTION

A SERIES OF SPECIAL MACHINE TOOLS HAVE BEEN DEVELOPED for the production of cutting tools. They are designed to perform either a single or several operations. Such machine tools find applications in various stages of the manufacturing cycle, beginning with the blank and up to the sharpening of the finished tool.

Many Soviet tool plants employ change-over type transfer machines. These machines were designed by the *Orgstankinprom Designing Institute* on the basis of modified standard general-purpose machine tools. Up to 22 machines have been used in each line. Most of the main operations in the production of machine and hand taps are performed by these transfer machines. However, to achieve the complete automation of tap production, beginning with the blank and ending with the packing operation, it is necessary to develop automatic machine tools, that can be built into a transfer machine, for such critical operations as thread grinding and sharpening.

Semiautomatic precision thread grinders of the general- and single-purpose types are widely used at the present time in the manufacture of taps, thread gauges, thread-milling cutters, etc. These machines, operating on complex *production cycles, must comply* with very high accuracy requirements.

Shank-type tools are turned in special automatic and semiautomatic copying lathes with hydraulic tracing systems.

Jig borers are another type of machine tool that find extensive application in tool production.

Along with special machine tools, general-purpose models are also used to make cutting tools. These include cylindrical and surface grinders, broaching machines, centring machines, etc. Thus, Swiss-type automatic screw machines turn blanks in the automatic transfer machine for tap production.

Specialized machines, based on general-purpose models, are used for *certain operations. As a rule, in these cases,* the principal units of the initial machine, such as the main and feed drives, are utilized, while special new units and mechanisms are *built into the machine for performing* the required machining operations and for automating the cycle. An example of such specialization is the three-position semiautomatic milling machine, model МН-10, for producing helical flutes in end mills. Its design is based on the universal horizontal milling machine, model 6Н82.

The most typical special and specialized machine tools designed for tool production are:

(1) Automatics for cutting up cold-drawn (sized) bar stock into blanks for twist drills and other similar tools.

(2) Automatic and semiautomatic lathes for turning cylindrical and tapered surfaces on drill, reamer and tap blanks.

(3) Automatic and semiautomatic machines for milling drill and tap flutes, drill tangs and tap shank squares.

(4) Precision and high-accuracy thread-cutting machines.

(5) Thread grinders for grinding the thread on tap blanks, cylindrical thread-rolling dies and certain types of milling cutters.

(6) Thread-rolling machines for rolling thread on taps and other tools.

(7) Semiautomatic machines for grinding gear-shaping and shaving cutters.

(8) Universal and specialized tool grinders for sharpening different types of cutting tools: single-point tools; twist, flat and gun drills; hobs; face milling cutters; segment saws, taps, broaches, etc. This group also includes machines for lapping carbide-tipped tools.

Representative examples of machine tools belonging to these groups, as well as jig borers and an automatic transfer machine for tap production, are considered in the following chapters.

CHAPTER 15
MACHINE TOOLS FOR BLANK MANUFACTURE

15-1. Automatic Vertical Cutting-Off Machine, Model ЛА-17

The model ЛА-17 automatic is intended for cutting off cold-drawn (sized) or hot-rolled bar stock to make the blanks of shank-type cutting tools.

The distinguishing feature of this machine is that the bar stock is held in a vertical position during operation so that it occupies considerably less floor space of the shop. The stock is fed out by gravity to the stop for cutting off the next tool blank. It is cut off with two single-point tools which travel toward the axis of the rotating stock at the rate of feed (Fig. 277).

The cut-off tools are ground so that, simultaneously with the cutting-off *operation, they turn a point with an included angle of 118° on the lower end* of drill blanks, the upper end remaining square to the drill axis.

Model ЛА-17 (Fig. 278) handles blanks in a diameter range from 9 to 28 mm. A carbide-tipped roughing tool is set up in the toolholder of the left-hand slide; the finishing tool in the right-hand slide has a tip of high-speed steel, grade P18.

A three-jaw chuck with wedge-type clamping facilities is used for holding both cold-drawn and hot-rolled bar stock.

The automatic has a very high production capacity. For example, it can cut off about 190 pieces of stock, 14 to 16 mm in diameter, per hour. A single operator can tend several such machines.

Data concerning the model ЛА-17 automatic are listed in the following specifications:

Brief Specifications of the Automatic
Vertical Cutting-Off Machine

Bar capacity, mm:	
minimum diameter .	9
maximum diameter .	28
Length of blanks cut off, mm:	
minimum	76
maximum	140
Number of spindle speeds .	6
Range of spindle speeds, rpm	220 to 658
Number of tools operating simultaneously . . .	2
Travel of tool slides, mm:	
L.H slide	14.5
R.H. slide	16.25
Spindle and feed drive motor:	
type	T42-6/4
power, kW . . .	2; 2.5
Speed, rpm	950; 1,420

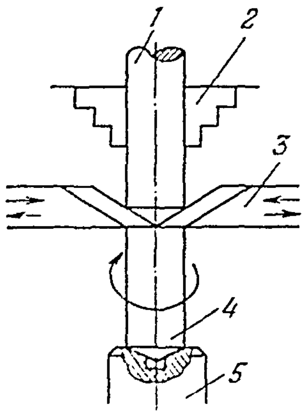


Fig. 277. Cutting off drill blanks:

1—bar stock; 2—three-jaw chuck; 3—cut-off tool; 4—blank; 5—stock stop

The automatic cutting-off machine comprises the following principal units: base, spindle column, tool heads, drive of the hydromechanical clamping arrangement, stop housing and the swing-back stock stop, loading device, coolant system and electrical equipment.

Box-shaped base *1* carries all the other units of the machine, spindle column *2* being mounted on its upper surface. The base houses the two-speed main drive motor mounted on a pivoted plate, and the panel with the electrical devices.

The right-hand cavity of the base serves as a reservoir for the cutting fluid. A bracket holding coolant pump *14* is mounted on the rear wall of the base.

The spindle column housing contains the spindle, power travel mechanism of the heads and the mechanism for clamping and unclamping the bar stock.

Mounted on the top surface of column *2* are drive *12* of the hydromechanical clamping device with a vane pump, type Л1-Ф5, having a delivery of 5 litres per min at a pressure up to 50 kg per sq cm, and a 1-kW electric motor running at 960 rpm.

The hydraulic cylinder for stock clamping is mounted at the upper end of the spindle. The left- and right-hand tool heads, *7* and *6*, are arranged at the front, while stop housing *4* is below, mounted on vertical ways. A flange carrying swing-back stock stop *8* is located at the left.

These mechanisms, as well as spindle rotation, are driven by two-speed electric motor *1* (Fig. 279*a*).

Rotation is transmitted from shaft *I* of the motor through a belt drive with two-step pulleys *2* and *7* to shaft *II*, and further, through bevel gears *12* and *13*, to the hollow spindle through which the bar stock passes. The required spindle speed is obtained by installing the corresponding change pulleys and by switching over the drive motor to one of its two available speeds.

Secured on shaft *II* is worm *8* which transmits rotation through worm wheel *19* to shaft *IV* and further, through change gears *a* and *b*, to shaft *V* on which worms *6* and *21* are mounted. Worm wheels *4* and *20*, meshing with worms *6* and *21*, transmit rotation to horizontal shafts *VI* and *VII*.

Cylindrical drum *9*, carrying two cams, is secured on vertical shaft *VIII* (Fig. 279*a*). Through a lever, one cam actuates a three-way valve which admits oil delivered by pump *11* (Fig. 279*a*) through rotating joint *11* (Fig. 280) to the upper and lower ends of the hydraulic cylinder. Hydraulic cylinder *10*, mounted on the end of spindle *7*, is designed for clamping and

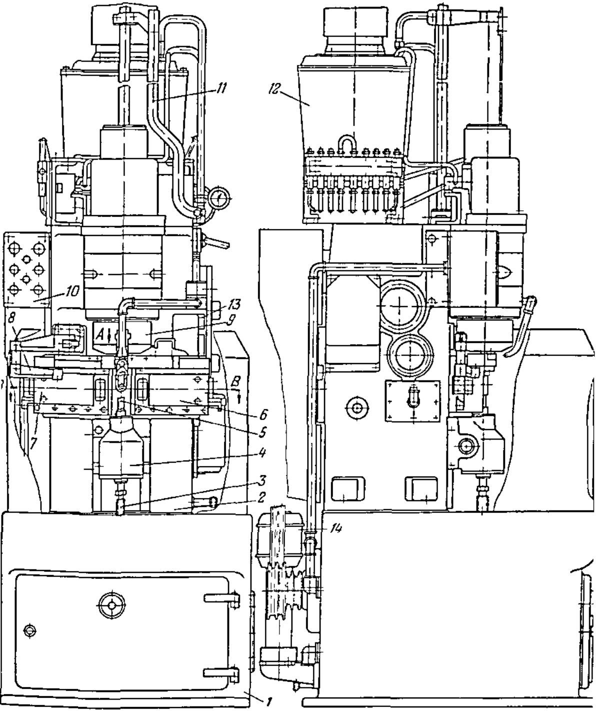


Fig. 278. Automatic vertical cutting-off machine, model ЛА-17

1—base; 2—spindle column, 3-[illegible] adjusting the stock stop, 4—stop housing, 5—adjustable
stop; 6 and 7—tool heads, 8—[illegible]
12—drive of the hydromechan[illegible]
when [illegible]

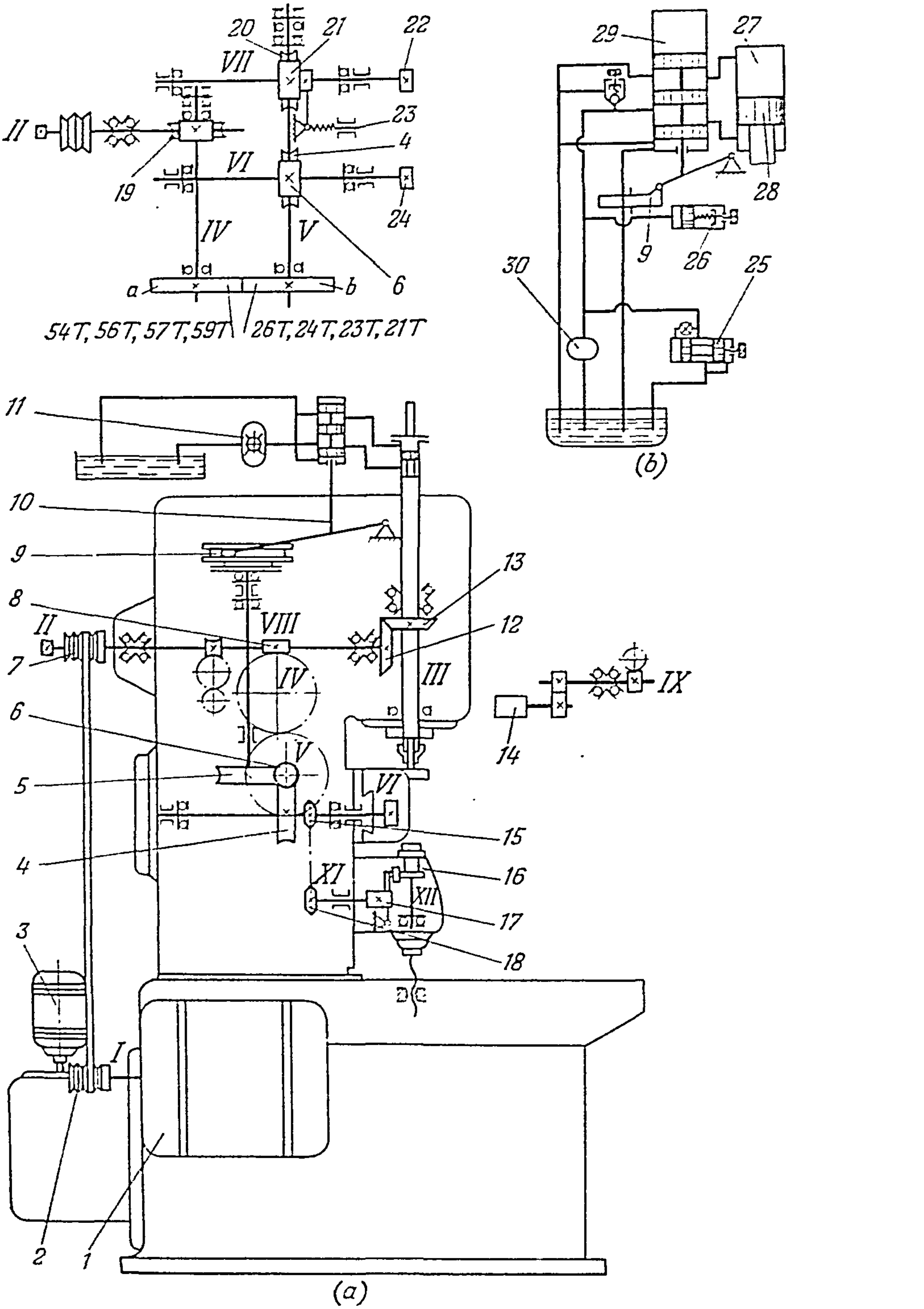


Fig. 279. Diagrams of the automatic vertical cutting-off machine, model ЛА-17:

(*a*) gearing diagram; (*b*) hydraulic circuit diagram of the clamping arrangement; *1*—main drive motor; *2* and *7*—change pulleys; *3*—coolant pump; *6*, *8* and *21*—worms; *4*, *5*, *19* and *20*—worm wheels; *9*—cylindrical cam drum; *10*—rod of the hydraulic cylinder; *11*—vane pump of clamping arrangement; *12* and *13*—bevel gears; *14*—pump of the lubricating system; *15* and *18*—chain sprockets; *16*—stop housing; *17*—stock stop mechanism; *22* and *24*—cams for traversing the right- and left-hand tool slides; *23*—ejector; *25*—backpressure valve; *26*—pressure switch; *27*—hydraulic cylinder; *28*—piston; *29*—three-way valve; *30*—vane pump

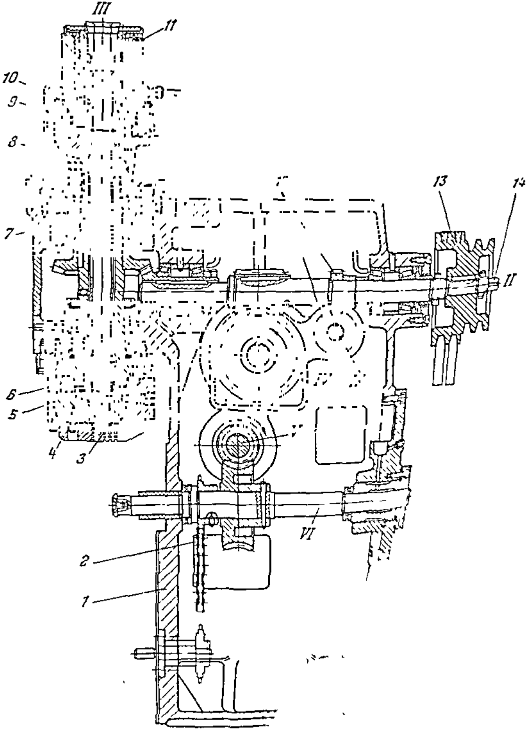


Fig. 280. Spindle column of the automatic [illegible]

1—housing, 2—chain drive of the stock stop mech[illegible]
5—master jaws, 6—chuck; 7—spindle; 8—tub[illegible]
12—spiral gearing to lubricating pump, 13—drive[illegible]

releasing the bar stock. The stock is clamped in a three-jaw universal (self-centring) chuck *6* having a wedge-type locking member *3*. Working pressure of the oil in the cylinder is 13 kg per sq cm. Any drop in pressure in the hydraulic system actuates pressure switch *26* (Fig. 279*b*) and stops the main drive motor.

Piston *9* (Fig. 280) of hydraulic cylinder *10* is rigidly secured to tube *8* whose lower end is linked to wedge-type locking member *3* of chuck *6*. Member *3* is linked, in turn, to three master jaws *5* on which top jaws *4* are secured with screws. The chuck is fastened by screws to the flange of the spindle and is located on a tapered pilot.

Upon upward travel of the piston, the jaws move radially inward and clamp the bar stock. After this the stock rotates together with the spindle, and the feed motion of the heads with the cutting tools begins.

Both the left- (*6*) and right-hand (*7*) tool heads (Fig. 281) consist of guide *12* fastened by screws *16* to the base, and slide *13*, travelling along the ways of the guide.

Toolholder *15*, accommodated in a rectangular recess of slide *13*, can be adjusted, in setting up the machine, along guide strip *14*, secured to slide *13*. The set-up toolholder is clamped on the slide by screws *4*.

The tool slides are traversed by cams *22* (for finishing) and *24* (for roughing) mounted on the ends of shafts *VI* and *VII* (Figs. 279*a* and 281). These cams actuate the slides through rollers *2* and *11* mounted in the slides, thereby providing rapid approach of the tools to the stock and the working feed.

The rate of feed, expressed here in millimetres per spindle revolution, is set up by installing the required change gears *a* and *b* (Fig. 279*a*) on shafts *IV* and *V*, and the corresponding cams on shafts *VI* and *VII* for each range of stock diameters. A safety clutch on shaft *IV* prevents overloading of the feed mechanism.

The set of change gears furnished with the machine enables six rates of feed to be obtained in the range from 0.05 to 0.08 mm per revolution. Two coil springs *3* (Fig. 281) hold rollers *2* and *11* constantly against cams *22* and *24* and return the slides after the stock is cut off. The rollers are mounted on eccentric pins providing a certain degree of adjustment of the innermost position of the slides.

When a blank has been cut off, the clamping mechanism releases the stock, cam *9* (Fig. 279*b*), mounted on shaft *VII* (Fig. 279*a*), actuates lever *8* (Fig. 281), and ejector *10* pushes the cut-off blank into the discharge trough.

In the course of each cycle, as the tools approach the axis of the stock, the second cam mounted on drum *9* (Fig. 279*a*) operates a limit switch which increases the motor speed, thereby maintaining an approximately constant cutting speed.

The bar stock in tool production is either high-speed steel, grade P18 or P9, or one of its substitutes.

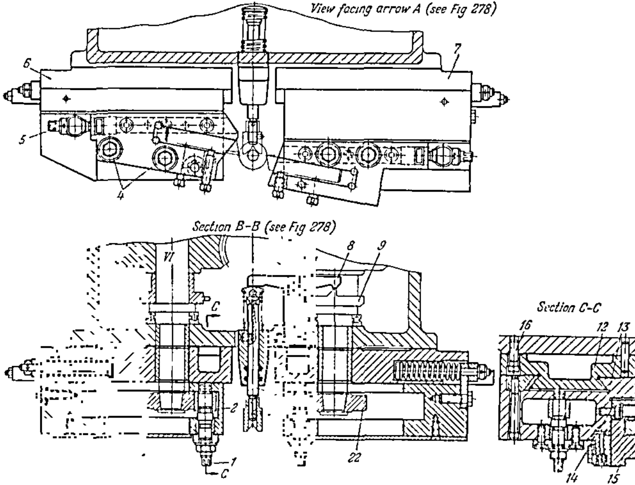


Fig. 281. Tool heads of the automatic vertical cutting-off machine, model ЛА-17:

1—eccentric pin, 2 and 11—rollers, 3—spring, 4—clamping screws, 5—holder adjusting screw; 6—L.H. tool head; 7—R.H. tool head, 8—ejector lever; 9—cam, 10—ejector; 12—guide; 13—tool slide; 14—guide strip; 15—toolholder; 16—screw fastening the guide

TABLE 48

Specifications	Ranges of bar stock diameters, mm					
	9 to 11	11.1 to 14	14.1 to 16	16.1 to 20	20.1 to 24	24.1 to 28
Spindle speed, rpm, at motor speed of 950 rpm	—	—	440	346	277	220
Cutting speed, m per min	—	—	22.2	22.4	21.0	19.4
Spindle speed, rpm, at motor speed of 1,420 rpm	658	518	658	518	415	330
Stock diameter, mm, at moment of motor switchover	—	—	9.7	12.0	15.4	19.3
Cutting speed, m per min	22.7	22.8	20.0	20.0	20.0	20.0
Travel, mm, of L.H. and R.H. tools at a motor speed of 950 rpm	—	—	3.15	4.0	4.3	4.35
Travel, mm, of tools at a motor speed of 1,420 rpm:						
L.H.	6.0	7.5	5.35	6.5	8.2	10.15
R.H.	7.75	9.25	7.1	8.25	9.95	11.9

Table 48 lists the machined diameters at which the motor is switched over for each range of stock diameters, as well as the corresponding cutting speeds.

Stop housing *4* and adjustable stop *5* (Fig. 278) serve to restrict stock feed to the specified blank length. The mechanism for moving the stop is enclosed in a separate housing, mounted on the front ways of spindle column *2* and supported by screw jack *3*.

Stop movement is kinematically linked with slide travel in such a manner that when the slides travel inward to the stock axis, the stop moves downward. As the slides withdraw to their initial positions, the stop moves upward to its working position, corresponding to the lower end of the stock.

From shaft *VI* (Figs. 279*a* and 281) motion is transmitted through a chain drive, cam and lever mechanism to a reciprocating rack that meshes with a pinion, and further through the face teeth of a sleeve in whose hole adjustable stop *5* (Fig. 278) is secured. This stop can be set up to cut off blanks of various lengths in a definite range. If necessary, the stop can be interchanged with one of a different size.

The stop is accurately adjusted to the specified length of blank to be cut off with the aid of screw jack *3*.

The swing-back stock stop *8* is used to trim off the uneven end of a new piece of bar stock after loading it into the machine. The position of the working surface of the stop in reference to the spindle is constant, and is designed to cut off the minimum amount sufficient to square up the stock.

When the bar stock is clamped and cutting begins, the lever of the stop is retracted by swinging it to one side by hand. Further restriction of stock feed-out, in cutting up the rest of the bar, is accomplished by adjustable stop *5*. A lever pivoted on the stock clamping chuck turns by spring action when the bar of stock is completely used up and, through a lever system, actuates a limit switch which turns off the main drive motor.

Loading device *11* (Fig. 278) constitutes of an upright, fastened by screws to the top wall of spindle column *2*, on which two brackets are rigidly mounted to support the bar stock. The rigidity of the arrangement is further increased by bracing the top of the upright against the nearest shop wall or column of the building.

Bar stock must be straightened before it is cut off. The camber must not exceed 0.3 mm per metre of length. The attainable accuracy in the length of the cut-off blanks is ± 0.5 mm for stock up to 20 mm in diameter and $+0.5$ mm for larger diameters, while the surface finish is within the stipulations of the 4th class according to the USSR Standard.

CHAPTER 16

SPECIAL SEMIAUTOMATIC LATHES

16-1. Semiautomatic Tracer-Controlled Lathe, Model BT-10M

Hydraulic Circuit of the One-Dimensional Tracing System of Semiautomatic, Model BT-10M

Hydraulic tracing systems are widely employed in turning the blanks of parts of complex shape. In essence, these tracing systems are servosystems of automatic control.

Peculiar to these systems is the application of a special tracing device, sensitive to unbalance, which constantly compares tool motion with the preset programme—the template profile. The instant unbalance occurs, a signal is transmitted to the operative unit to eliminate the unbalance.

Duplicating machines with hydraulic tracing systems mainly use flow controls whose advantage is their simpler construction. Circuits of this type employ fixed-displacement pumps. The hydraulic circuit diagram of the tracing system used in model BT-10M is shown in Fig. 282.

The motion of transverse copying slide *2* is controlled by tracer valve spool *5* having a stylus *6* at its end. Body *4* of the tracer valve, in a bore of which the valve spool travels, is connected to transverse slide *2* and the rod of piston *3* of the power cylinder. The latter is mounted on the saddle.

The blank is turned to a template which has a profile exactly like that required on the finished workpiece. The longitudinal feed is not related to the cross (tracing) feed and has a constant adjustable value. The tool feed is in the direction of the resultant of the longitudinal and cross feeds and is a variable value depending upon the angle the portion of the profile being turned makes with the work axis.

This tracing system operates in the following way.

Oil from pump *1* enters rod end F_2 of the hydraulic cylinder and, through variable-flow valve *7*, to tracer valve *4* and head end F_1 of the hydraulic cylinder. Thus ends F_1 and F_2 of the cylinder are constantly under pressure. This ensures higher sensitivity, rigidity and vibration-proof properties.

As tracer valve spool *5* moves up or down, in accordance with the profile of the template, orifice *a* is varied in the valve, increasing or decreasing the resistance to oil flow. This determines the direction of travel and the velocity of piston *3* and, consequently, those of the tracing slide.

At the initial moment, before stylus *6* comes into contact with the template, tracer valve spool *5* is shifted downward by a spring, closing orifice *a*.

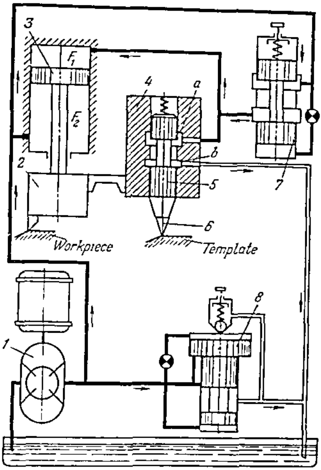


Fig. 282 Hydraulic circuit diagram of the one-dimensional tracer-controlled system used in the model BT-10M semiautomatic lathe

The resistance of the tracing valve will be at a maximum, in this case, and piston *3*, together with the slide and the body of the tracing valve, moves rapidly downward to the blank until the stylus reaches the template. As the stylus comes into contact with the template, the valve spool is shifted upward (in respect to the body) opening the passage for oil flow through orifices *a* and *b* to the tank.

At this, the pressure in cylinder end F_1 drops and piston *3* with slide *2* continues to travel downward, but with a lower (tracing) feed, if a descending curve is being reproduced.

At a certain magnitude of orifice a, the pressure in head end F_1 will become equal to one half of the pressure in rod end F_2 and, since the effective areas of the piston at the two ends have a 2 : 1 ratio, feed of the tracing slide ceases. This position corresponds to the turning of a cylindrical surface.

As the stylus reaches an ascending profile, the tracer valve spool is shifted more in respect to the body, opening orifice a to a still greater extent. In this case, the pressure in head end F_1 will be less than one half of that in rod end F_2 and the tracing slide will travel upward.

The rate of slide travel is determined by the amount of fluid that the throttling orifice a of the tracer valve can pass at the given pressure difference.

In the servomechanism under consideration, travel of the piston in the power cylinder results in motion of the body of the tracer valve. This produces the feedback feature between tracer valve spool *5* and power cylinder piston *3*.

Because of the motion of the body of the tracer valve, the command pulse gradually weakens and, as soon as the length of slide travel equals the movement of the stylus, the pulse becomes equal to zero.

The use of variable-flow valve *7* in a hydraulic tracing system with a differential cylinder, in place of a throttle valve with a constant orifice, offers certain advantages. The speeds of up and down rapid traverse are the same in a system with a variable-flow valve, as distinct from one with a throttle valve. The application of a variable-flow valve also increases tracing accuracy and enables the system to operate on a lower and constant pressure.

Other merits of the given tracing system are the smooth travel, the availability of infinitely variable tracing feeds, low inertia providing for rapid action, and a sufficiently high machining accuracy.

Balanced-piston relief valve *8* maintains a constant pressure in the system.

Purpose and design features. The model BT-10M semiautomatic (Fig. 283) is intended for turning blanks of shank-type cutting tools, such as drills, reamers, end mills, etc. The blanks are clamped between centres and are turned by a hydraulic tracing slide to a round template or a master.

Separate parts of the tool or the whole length can be turned in the machine in a single or several passes.

All motions of the machine, with the exception of workpiece rotation, are powered by the hydraulic system which effects longitudinal feed and rapid withdrawal of the saddle, tracing movement, extension of the tailstock spindle, releasing and starting the headstock spindle, and cooling of the cutting tool.

The spindle is driven directly by a two-speed electric motor through V-belts.

A brake, built into the driven pulley mounted on the spindle, is applied by a spring and is released by a hydraulic plunger.

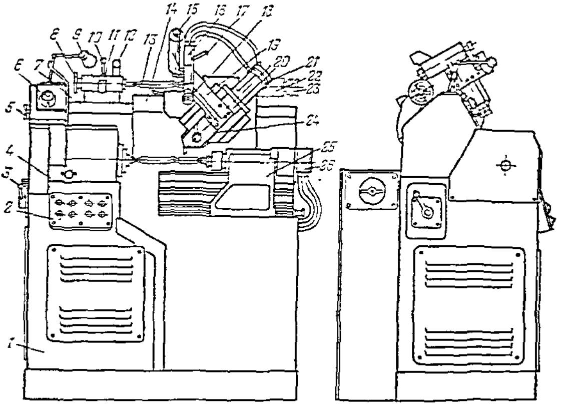


Fig. 283. Semiautomatic tracer-controlled lathe, model BT-10M:

1—bed; *2*—control panel; *3*—spindle speed-change lever; *4*—headstock; *5*—main line switch; *6*—knob with dial for setting the carriage feed, *7*—base of the carriage unit; *8*—handwheel for adjusting the left-hand centre to set up the template axially; *9*—left-hand centre stock; *10*—lever for clamping the centre stock housing; *11*—stop for limiting the length of the surface machined; *12*—lever for clamping the centre stock spindle; *13*—round template; *14*—saddle; *15*—pickup; *16*—pickup slide; *17*—lever for clamping the pickup slide; *18*—head with dial for adjusting the pickup slide, *19*—bracket of the pickup slide; *20*—tracing slide; *21*—hydraulic cylinder of the tracing slide; *22*—right-hand centre stock; *23*—handwheel for adjusting the right-hand centre to set up the template axially; *24*—toolholder; *25*—tailstock; *26*—hydraulic cylinder for extending and retracting the tailstock quill

Motor speeds are changed with a drum-type switch. The motor is mounted on a hinged plate inside the bed. This arrangement facilitates belt tensioning.

Data on the model BT-10M semiautomatic are listed in the following.

Brief Specifications of the Semiautomatic Tracer-Controlled Lathe

Diameter turned, mm:	
maximum	50
minimum	12

Length turned, mm:	
maximum	350
minimum	80
Travel of saddle (longitudinal), mm	400
Travel of tracing slide (cross), mm	35
Maximum depth of profile turned, mm	20
Maximum angle of profile turned, deg	15
Spindle speeds, rpm	720 and 1,450
(with different driving pulley)	500 and 1,000
Longitudinal feed of saddle (infinitely variable), mm per min	100 to 800
Speed of rapid withdrawal of saddle, m per min	1.3
Speed of rapid withdrawal of tracing slide, m per min	1.3
Power of two-speed spindle drive motor, kW	5.2/7

Headstock *4* is secured at the left-hand side on the front horizontal surface of bed *1* (Fig. 283) while tailstock *25* is mounted at the right-hand side on an inclined surface with a V-way. The tailstock can be moved along the way and clamped in a position to suit the length of the work. The tailstock centre is inserted into the inner spindle which runs in antifriction bearings in the quill of the tailstock. The design of this built-in revolving centre enables the machine to operate at high speeds. The tailstock quill is hydraulically extended and retracted.

Base *7* of the carriage unit (Figs. 283 and 284*a*) is fastened on the horizontal top surface of the bed behind the headstock and tailstock. This base has inclined flat ways along which saddle *14* travels. A dovetail guide at the upper rear part of the base mounts left- (*9*) and right-hand (*22*) centre stocks between whose centres template *13* is held.

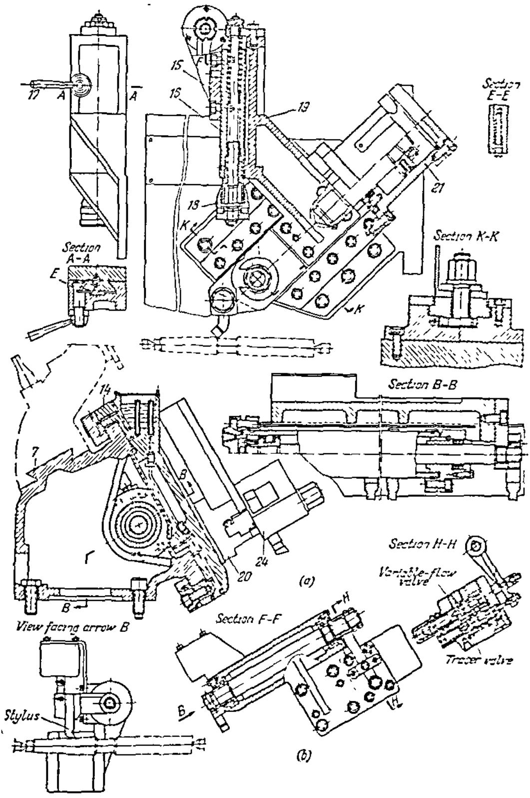
The template is accurately set up axially by turning handwheels *8* and *23* to extend or retract the spindles of the stocks. The spindle of the right-hand stock is spring loaded.

Longitudinal feed of the saddle is effected by a hydraulic cylinder built into base *7*.

Transverse hydraulic cylinder *21* feeds tracing slide *20* along the inclined ways of saddle *14*. Mounted on the slide are toolholder *24* and cast bracket *19* with dovetail ways along which slide *16* of the pickup travels. These ways provide the linkage between tracing slide *20*, to which bracket *19* is rigidly secured, and pickup *15*, fastened to the upper surface of slide *16*.

The overhang of the tracing slide, as well as the setting to the depth of cut are adjusted by turning head *18* with its circular scale to move the slide of pickup *15*.

After making the required adjustments, the pickup slide is firmly clamped on bracket *19* by turning lever *17*.



17
A
A
15
16
13
Section E-E
21
18
K
Section A-A
E
Section K-K
K
Section B-B
14
7
B
20
24
(a)
B
Section H-H
Variable-flow valve
Tracer valve
Section F-F
H
H
View facing arrow B
Stylus
B
(b)

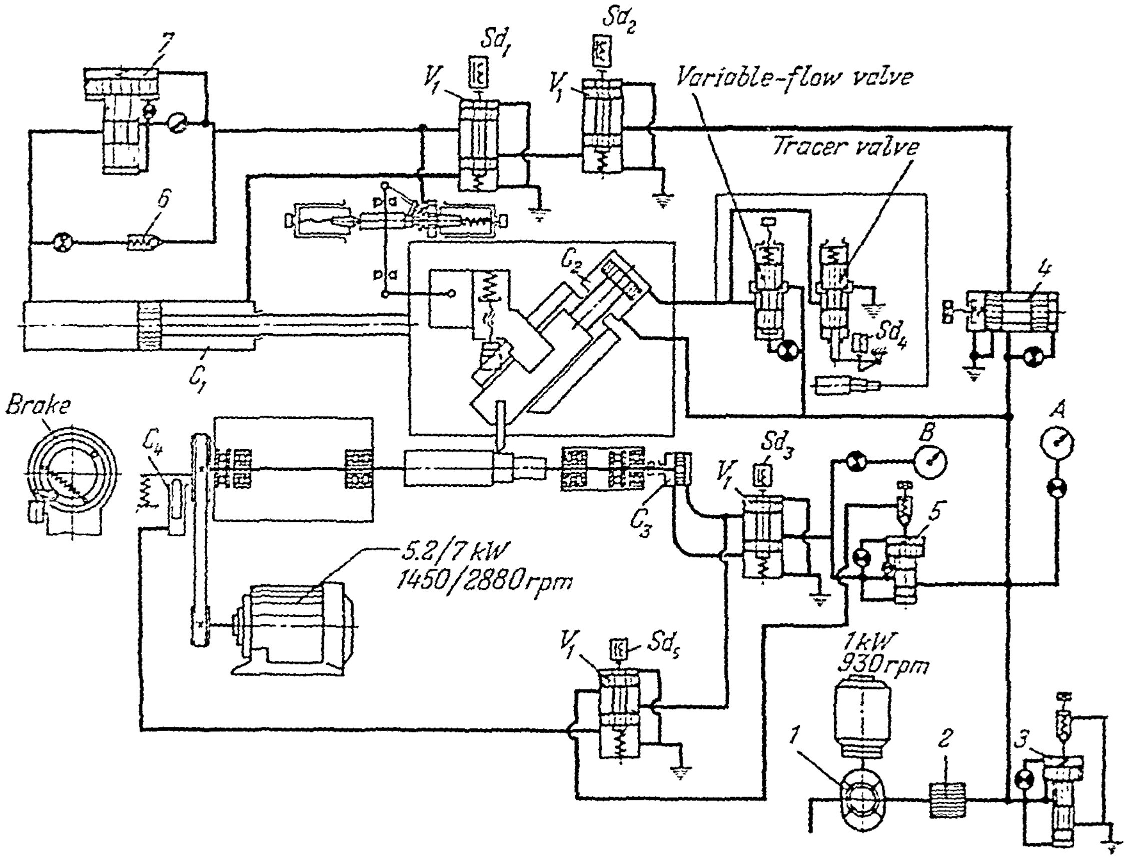


Fig. 285. Combined hydraulic circuit and gearing diagram of the semiautomatic tracer-controlled lathe, model BT-10M

The pickup (Fig. 284*b*) has a bracket by means of which it is fastened to the slide of a housing containing the tracer and regulating valve spools (the latter being part of the variable-flow valve) and a system of levers by means of which all movements of the stylus are transmitted to the tracer valve.

Combined hydraulic circuit and gearing diagram (Fig. 285). Oil is delivered by pump *1* through plate filter *2* and balanced-piston relief valve *3* into the hydraulic system. The relief valve is adjusted to a pressure of $p = 20$ kg per sq cm which is checked in the main circuit by pressure gauge *A*.

Oil flows along a pipeline to the variable-flow valve and rod end of hydraulic cylinder C_2 of the tracing slide. From the variable-flow valve oil is admitted to the head end of cylinder C_2 as a result of which the tracing slide advances to the work.

In its forward motion, the stylus of the tracing valve runs up against the template and, compressing the spring, pushes back the tracer valve spool, opening a slit for oil drain and thereby reducing the pressure in the head end of cylinder C_2. When the pressure in this end of the cylinder reaches a value one half of that in the rod end, the tracing slide will be in equilibrium. This corresponds to the turning of a cylindrical portion of the work. Raising and lowering of the stylus corresponds to a like motion of the tracing slide. Thus the cutting tool exactly reproduces the motion of the stylus.

A slit of constant cross section is maintained in the tracer valve. This, in turn, maintains a constant difference in pressure in the ends of cylinder C_2.

If the stylus runs out of contact with the template, the tracer valve spool will be returned to its initial position by spring action and the tracing slide will move downward.

At the same time, oil passes through backpressure valve *4* and, if solenoids Sd_1 and Sd_2 are energized, enters the rod end of cylinder C_1 which provides for longitudinal motion of the carriage at the working feed.

The oil from the head end of the cylinder flows through the pressure-compensated flow-control valve *7* which ensures a constant rate of feed. Feed is changed by turning knob *6* of the flow-control valve (Fig. 283). The dial divisions of the knob correspond to definite rates of feed which are established in testing the machine. Only solenoid Sd_2 is energized for rapid withdrawal of the carriage (Fig. 285) and oil passes through both valves V_1 and check (nonreturn) valve *6* to the head end of hydraulic cylinder C_1, traversing the carriage to its extreme right-hand position.

Oil enters hydraulic cylinder C_3 to advance the tailstock centre, securing the work, through reducing valve *5* which is adjusted, depending upon the type of workpiece, to a pressure slightly less or equal to the pressure in the main circuit. This pressure is checked on pressure gauge *B* of the reducing valve.

When solenoid Sd_3 is energized, oil is admitted through valve V_1 into the rod end of cylinder C_3 to retract the tailstock spindle.

If solenoid Sd_3 is de-energized, the oil passes through valve V_1 to the head end of cylinder C_3 advancing the tailstock spindle. Solenoid Sd_5 is simultaneously energized and oil is admitted through the valve and under the plunger of cylinder C_4 for operating the spindle brake. This releases the spindle pulley and operates a limit switch which switches on headstock spindle rotation.

Operation of the machine. For lathe operation on a semiautomatic cycle the cycle switch is turned to the SEMIAUTO position The operator presses the START push button of the hydraulic pump, thereby switching on the pump drive motor.

Pressing the RETRACT push button of the tailstock centre energizes solenoid Sd_3 (Fig. 285) and the centre moves to the right.

Releasing the RETRACT push button, the operator loads the blank on the line of centres. Since solenoid Sd_3 is de-energized, the tailstock spindle advances and clamps the blank between the centres.

When the START push button of the spindle is pressed, solenoid Sd_5 is energized and the brake releases the spindle driving pulley. At the same time the magnetic starter of the spindle drive motor is closed, and solenoids Sd_1 and Sd_2 are energized (the motor speed depends upon the position of the drum switch). This starts the working feed of the carriage and the workpiece is turned to the required contour to the template.

At the end of the pass a limit switch is operated. It switches off the spindle drive motor and de-energizes solenoid Sd_5. At this, braking occurs and the motor is stopped. Then solenoids Sd_2 and Sd_4 are energized, withdrawing the stylus from the template, and the carriage is rapidly returned to its initial position.

In its extreme withdrawn position the carriage closes a limit switch preparing the circuit for the next cycle which is started by pressing the START push button again, after loading a new blank.

The electric circuit is designed so that the work can be turned in several passes if necessary.

To set up the machine the operation selector switch is turned to the HAND position in which all the drives are controlled independently and manually.

16-2. Semiautomatic Tracer-Controlled Lathe, Model MP105

Construction and brief specifications. Model MP105 (Fig. 286) is a hydraulic tracer-controlled semiautomatic, equipped with a device for automatically loading the blanks and unloading the turned workpieces. It finds application in the tool industry for turning drills, taps, reamers, etc.

The blank is turned to obtain a specified contour with a single tool, using a hydraulic tracing device, to a template or master mounted on the machine.

The provision of automatic multiple-pass facilities enables several passes to be employed in turning blanks with large or nonuniform allowances, where there is a large difference in the diameters of adjacent surfaces of the workpiece.

The vertical arrangement of the units provides reliable protection for the operator against chips which drop away freely from the carriage, thus facilitating operation of the machine. The provision of loading and unloading devices enables a single operator to tend several semiautomatics simultaneously.

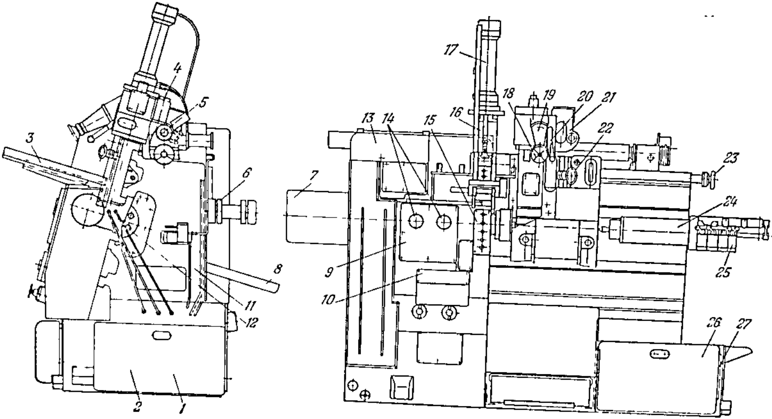


Fig 286. Semiautomatic tracer-controlled lathe, model MP105:

1—tailstock quill control panel, *2*—valve panel, *3*—loading trough; *4*—hydraulic tracing stylus, *5*—mechanism for setting up the templates, *6*—unloading device, *7*—clamping cylinder, *8*—discharge trough, *9*—headstock, *10*—setting-up (manual) control panel, *11*—bed, *12*—tailstock adjustment screw, *13*—mounting for dogs that operate the limit switches, *14*—facilities for shifting the cluster gears in the headstock, *15*—operation control panel; *16*—loading device, *17*—loading device cylinder, *18*—handwheel for setting the tool to the depth of cut; *19*—tracing slide; *20*—lever for clamping the stylus slide; *21*—mechanism for setting the stylus, *22*—handwheel for adjusting the stylus stop; *23*—handwheel for setting the template; *24*—tailstock, *25*—tailstock quill controls, *26*—tracing slide control panel, *27*—hydraulic oil tank

The tracing method of turning tool blanks allows the production capacity to be substantially increased. This is due in part to the reduction of the time required to set up and change over the machine (operating with one tool) from one job to another, and to the higher cutting feeds and speeds that can be applied.

The high power of the main drive motor and the ample rigidity of the machine enable tools tipped with up-to-date cemented carbides to be used, and turning to be done with heavy feeds, removing chips of large cross section. Springing of the work is reduced since it is turned with a single tool. This and the high accuracy of the servomechanism tracing system ensure exceptionally high machining accuracy. Data on the model MP105 semiautomatic are given in the following specifications.

Brief Specifications of the Semiautomatic Lathe, Model MP105

Diameter turned, mm:	
minimum	20
maximum	90
Length turned, mm:	
minimum	150
maximum	450
Range of spindle speeds, rpm	162 to 2,040
Number of spindle speeds	12
Resultant working feeds of tracing slide, mm per min:	
minimum	20
maximum	700
Speed of rapid traverse, m per min:	
longitudinal traverse of saddle	5.5
cross traverse of slide	1.06
Power of main drive motor, kW	14
Motor speed, rpm	1,450

The bed (Fig. 286) is a rigid box-shaped grey iron casting at the upper part of which the tracing slide ways are arranged at an angle of 45° to the vertical.

The headstock and the hydraulic cylinder for longitudinal travel of the tracing slide carriage are located at the left on the bed. Special ways for the tailstock are arranged at the right. Mounted on the top surface of the headstock is the loading trough while the unloading device is located at the rear of the bed. Also mounted on the top of the bed is the mechanism for indexing the template when the work is to be turned in several passes. The bed is mounted on two legs. The left leg accommodates the main drive electric

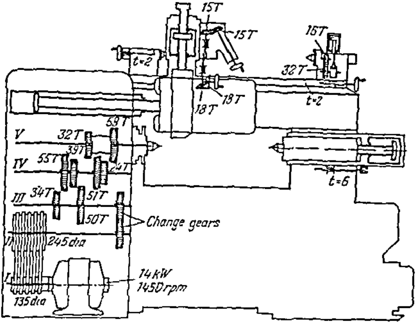


Fig. 287. Gearing diagram of the model MP105 semiautomatic

motor; the hydraulic drive of the machine is in the right leg. The drive motor is mounted on a special base whose adjustment controls belt tension.

Rotation is transmitted from shaft *I* (Fig. 287) of the motor through V-belts to drive shaft *II*, and further through change gears, fixed gears $34T$ and $50T$ on shaft *III*, and two sliding cluster gears on shaft *IV* to the spindle.

At the left end of the headstock is the hydraulic cylinder for actuating the headstock centre A serrated live centre is inserted in the taper socket of the spindle. The centre serves to hold the work and the serrations to transmit the driving torque to it.

The mechanisms of the speed gearbox are lubricated by a plunger pump.

A quill with an inner spindle and revolving centre is mounted in a bore of the tailstock. This quill can be extended and retracted, and is clamped in the required position by hydraulic cylinders. A bar secured to the rod of the cylinder for actuating the quill carries four cam dogs which operate limit switches at various points of quill travel to transmit various control signals.

The tailstock is adjusted along its ways by means of a screw secured in a bracket. The body of the tailstock is clamped in two planes. it is held by screws to the vertical surface of the ways, and by means of two taper gibs and clamping blocks to the lower locating surface of the ways.

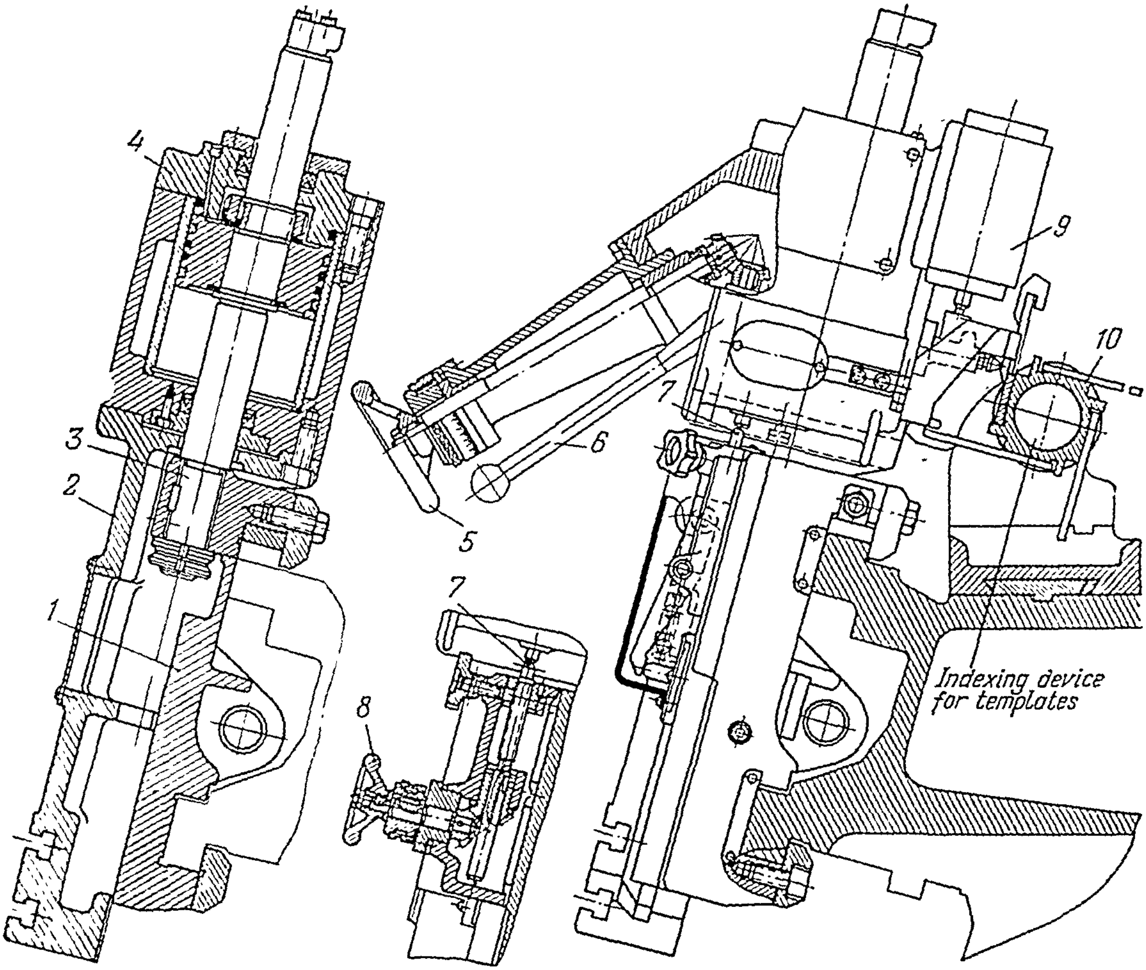


Fig. 288. Tracing slide carriage of the model MP105 semiautomatic

From 6 to 24 blanks, depending upon their diameter, are loaded into the trough from which they are removed by the loading device, arranged on the tracing slide carriage, and delivered to the line of centres.

Turned workpieces are removed from the centres by the unloading mechanism; then they run up against a stop and drop into the discharge trough (Fig. 286).

Tracing slide carriage (Fig. 288) consists of saddle *1* and the upper part. The saddle is traversed in the longitudinal direction by a hydraulic cylinder

mounted at the left part of the bed. The upper part of the carriage consists of vertical slide *2* and hydraulic cylinder *4*. T-slots at the lower end of the slide are used to set up and clamp a toolholder which has an adjustment for properly setting the cutting tool to the line of centres and a channel for feeding cutting fluid to the point of the tool. Rod *3* of hydraulic cylinder *4* is fastened rigidly to saddle *1*, while the cylinder is secured to the upper flange of slide *2*. The latter travels in the crosswise direction together with the cylinder to accomplish the tracing motion.

Mounted on the housing of hydraulic cylinder *4* is a slide on which are fastened housing *9* of the tracer valve and a lever with a stylus. To set up the machine to the required size of the work, the distance between the stylus and the cutting-tool point can be adjusted. The tracer valve slide is set to the required position by turning handwheel *5*; lever *6* clamps it in this position. If work is to be turned in a nonautomatic cycle in several passes to a single template *10*, stop *7* is used. The stop is adjusted by turning handwheel *8* so that the tool makes a cut on the work when there is a clearance between the stylus and the template. By lowering the screw of stop *7* (rotating handwheel *8*) after each pass, stock is gradually removed from the blank. In the last pass, the slide is controlled by the template. This is accomplished by lowering the screw of the stop until the stylus reaches the template or master. Employing this stop, cylindrical work can be turned without the need of a template or master.

A lubricator mounted on the saddle automatically feeds metered portions of oil to all points of lubrication upon each stroke of the cross slide.

Work can be turned in several passes, or cuts, in an automatic cycle by mounting the corresponding templates on the drum of the template indexing mechanism. This drum is mounted between the revolving centres of two stocks. The drum is indexed to put the next template into operation at the moment the tracing carriage returns to its initial position. Here the carriage operates a limit switch to energize the corresponding solenoid which, in turn, controls the hydraulic cylinder for drum indexing.

[illegible] urning [illegible] which the templates have already been mounted.

Principle of the Hydraulic Tracing System of the Machine

Unlike the one-dimensional tracing system with independent longitudinal feed, in the semiautomatic lathe under consideration the longitudinal feed is related to the tracing (cross) feed. An increase in cross feed automatically reduces the longitudinal feed and vice versa.

The hydraulic circuit diagram of the tracer-controlled system is shown in Fig. 289.

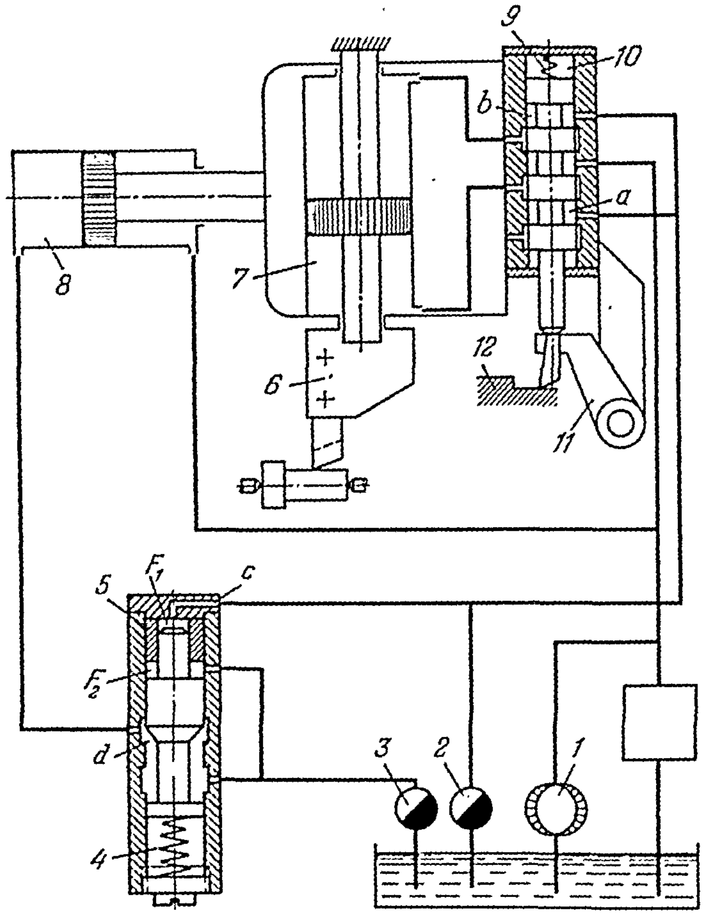


Fig. 289. Hydraulic circuit diagram of the tracer-controlled system used in the model MP105 semiautomatic

Tracing slide *6* is rigidly secured to the housing of tracer valve *10* and to cross feed cylinder *7*. The valve spool of the stylus is held by spring *9* against lever *11* and, through a tip shaped like the cutting-tool point, contacts the template *12*. The valve spool has crosswise motion upon longitudinal travel of the carriage.

As the stylus valve spool moves upward, oil enters the upper end of hydraulic cylinder *7*, and cross slide *6* begins to travel away from the work axis. When the stylus tip reaches a descending curve on the template, the valve spool is shifted downward by the spring. At this, oil enters the lower end of the cylinder and the slide travels toward the axis of the work. The housing of the tracer valve travels together with the cross feed cylinder thereby providing a feedback feature between the valve spool and the cylinder.

In turning a cylindrical portion of the work, the tracer valve occupies a neutral position (as shown in Fig. 289) and oil is not admitted to either end of cylinder 7.

The servomechanism drive operates as follows. From pump *1* oil is delivered to the housing of tracer valve *10* and, at the same time, to the right end of hydraulic cylinder *8* which provides for longitudinal travel of the carriage. The tracer valve spool, shifted up or down by the template and the spring, admits oil to one or the other end [illegible]

end, [illegible]

or *b* [illegible]

left end of cylinder *8* passes to flow-control valve *3* (for longitudinal feeds) through automatic pressure compensator *5*. The latter co-ordinates the speeds in the two perpendicular directions.

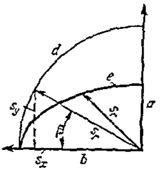


Fig. 290. Resultant tracing feed curves:
β—angle of inclination of the profile being turned; s_r—resultant feed

The pressure compensator is connected through port *c* with the drain ports of the tracer valve. Therefore, the spool of valve *5* is acted upon by the pressures established before flow-control valves *3* and *2*.

The sum of the forces acting on the spool of valve *5* in chambers F_1 and F_2 is counterbalanced by spring *4* Therefore, the position of the spool depends upon the sum of these forces.

With an increase in the angle of inclination of the profile being turned and, consequently, in the speed of the crosswise motion, a larger volume of oil is forced out of the cross feed cylinder. This raises the pressure of the oil before flow-control valve *2* and in chamber F_1 of the pressure compensator, and the total pressure overcomes the force of the spring. As a result, the spool is shifted downward and the area of orifice *d* is reduced. At this, the rate of longitudinal feed of the carriage will decrease until the total pressure drops to a value that is again counterbalanced by the spring.

In turning a cylindrical surface, the valve spool of the stylus occupies the neutral position, closing the entrance and exit of oil to and from both ends of the cross feed cylinder and thereby stopping cross feed of the slide. At this, the pressure drops in chamber F_1 of the pressure compensator and the sum of forces acting on its spool is reduced. As a result, the spool is shifted upward by spring *4*, increasing orifice *d* and, consequently, the rate of longitudinal traverse.

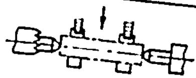
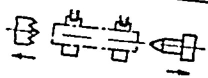
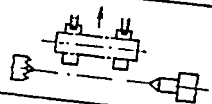
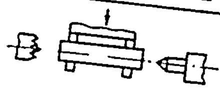
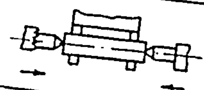
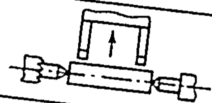
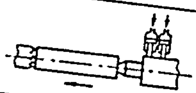
At definite ratios between the areas of the steps on the spool of pressure compensator *5*, t[illegible]

the tracing feed, [illegible]

In the latter cas[illegible]

Table 49

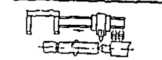
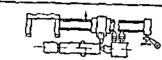
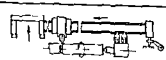
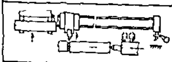
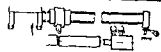
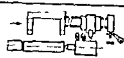
Automatic Cycle (after starting the machine) in Single- and Two-Pass Operation

Oper. elem.	Control device and unit		Operation element: sketch	Operation element: description	Sd1	Sd2	Sd3	Sd4	Sd5	Sd6	Sd7	Sd8	Sd9	Sd10	Sd11	Sd12	1PS
1	2PB		Starting pump drive electric motor 2M and setting mechanisms to initial position with manual controls														
2	1LS (loading trough) 7LLS (unloader) 4LLS (loader) closed; 3TLS (template) open		STOP	Initial position		–		–		–							
3	1RS rotary switch AUTO; 5PB CYCLE (start only); 20LS quill			Unloader is advanced to line of centres													
4	1LLS loader			Centre is retracted (from middle position)												⊕	
				Quill is retracted (from middle to extreme position)									⊕		–		
5	6LLS centre; 4QLS quill	first pass		Unloader is retracted								⊕					
6	1LLS unloader			Loader is lowered to the line of centres												⊖	
7	3LLS loader			Quill is advanced (to middle position)										⊕			
				Centre is advanced (work is held between centres)							⊕	⊖		–			
8	1QLS quill; 6LLS tailstock centre			Loader is raised (to middle position)							⊖		⊖				
9	2LLS loader			Quill is advanced to stop (centre with work are backed away under pressure)											⊕		
				Quill is clamped							⊕				–		

Single-pass operation

Two-pass operation — second pass

Two-pass operation

No.		Device	Sketch	Operation	1	2	3	4	5	6	7	8	9	10	11	12	13
10	a	3QLS Quill		Rapid longitudinal approach of the carriage	⊕	⊕											
	b	1MS Magnetic starter		Main drive motor 1M is switched on													
	c	1LS Tracing slide		Rapid cross approach	–	–		⊕	⊕								
	d	1PS Pressure switch		Tracing at first rate of working feed	⊕			–	⊕								⊕
		2LS Stylus (setting feed)		Tracing at second rate of working feed	⊕		⊕		⊕								⊕
	e	4LS Tracing slide		Rapid cross slide withdrawal to rear position	–		–	⊕	⊖								
	f	2TLS Template		Main drive motor is switched off													
11				Loader is raised from middle to upper position											⊕		
12		4LLS Loader		Quill is unclamped													
				Quill is retracted to middle position													
	j	3LS Tracing slide		Centre is retracted to extreme front position							⊖	⊕					
		(1LS) in initial position of carriage		Rapid longitudinal withdrawal of the carriage		⊕											
				Cycle repeated from element 3 in single-pass operation								–					
10	e	4LS 2TLS		Rapid withdrawal of cross slide to rear position	–			⊕	–								
	j	3LS		Rapid longitudinal withdrawal of carriage		⊕											
13		T 1TLS		Indexing of template drum						⊕							
				Cycle continues from element 10a in two-pass operation													

the angle of inclination of the various portions on the profile being traced.

The required ratio of the semi-axes *a* and *b* of the ellipse (Fig. 290, curve *e*) and, consequently, of the cross and longitudinal feeds, is obtained by proper adjustment of flow-control valves *2* and *3*.

Feed variation along an ellipse is of greater practical importance since in turning work with various profiles it is frequently desirable to have the rate of cross feed less than that of longitudinal feed.

Under these conditions, the hydraulic tracing system operates as a *one-dimensional system with interrelated longitudinal and cross feeds.*

The dimensions of the stepped spool in the pressure compensator are selected so that constant resultant feed (Fig. 290, curve *d*) is provided when flow-control valves *2* and *3* (Fig. 289) are opened the same amount. In this case, the resultant feed (Fig. 290) is

$$s_r = \sqrt{s_x^2 + s_y^2} = \text{const}$$

These conditions comply with the law of feed variation in a *two-dimensional tracing system.*

Automatic cycle. A combination of electric and hydraulic devices provides for the automatic cycle of the semiautomatic lathe. Certain elements of the cycle are controlled by adjustable cam dogs which actuate limit switches. Table 49 illustrates the automatic cycles of the machine, both for single- and two-pass operation. The second column lists the designations of the selector switches, and the units on which they are mounted and whose travel originates the commands for energizing and de-energizing the solenoids and for operating the pressure switches. The sketches and names of the operation elements give a clear idea of the order of these elements in the cycle:

(1) In single-pass operation, the cycle includes operation elements 1 through 12j, and repeating cycles begin with element 3.

(2) In two-pass operation, the first pass includes operation elements 1 through 10d and, as their sequel, elements from 10e to 13, inclusive. The second pass includes elements 10a through 12j; repeating cycles begin with element 3.

The hydraulic system is controlled by means of solenoids which receive command signals from limit switches and pressure switches (in-travel control).

The machine has three electric motors: for spindle rotation, for driving the hydraulic pump and for driving the screw-type chip conveyer.

The electric circuit of the machine is designed for automatic, semiautomatic and manual control (setting-up) operation, either of which can be obtained by turning the rotary packet switch to the corresponding position.

Automatic operation differs from semiautomatic operation in that the loading and unloading devices are put into operation. Manual control, used in setting up the machine, signifies that the carriage, spindle drive motor, tailstock quill, headstock centre and the loading and unloading devices are controlled separately and independently by hand.

The hydraulic circuit of this machine (Fig. 291) is supplied from an integrated pump installation constituting a double pump, type Л1ФС. The low-pressure section of this pump has a delivery of 35 litres per min at a pressure of 10 to 15 kg per sq cm and is for rapid traverse movement; the high-pressure section has a delivery of 12 litres per min at a pressure of 20 to 25 kg per sq cm and is intended for working feeds. The hydraulic circuit operates on mineral oil, grade Industrial 20 or Turbine Л.

Control of the automatic cycle, as well as control of the tracing process, is concentrated in the hydraulic panels which are connected to the discharge lines of the low- and high-pressure pump sections.

The hydraulic control panel of the tracing slide is designed on the principle of electrohydraulic controls with an automatic cycle. It provides for the following elements: (a) STOP in any position, (b) rapid longitudinal approach, (c) rapid cross approach up to contact of the stylus tip with the template, (d) copy turning (tracing) at the first and second rates of feed, (e) rapid withdrawal in the longitudinal and cross directions, and (f) FEED STOP at any position, after which the cycle is resumed.

The tracing slide panel includes the following devices: two directional valves, flow-control valves for the first and second rates of longitudinal feed, cross feed flow-control valve with a pressure compensator, sequence valve, pressure compensator and solenoid-operated pilot valves. These solenoids and their pilot valves control the following: Sd_1 controls the upper directional valve; Sd_2 controls the lower directional valve and unloads the rapid traverse pump section during working feed and in the STOP position; Sd_3 engages the second working feed; and Sd_4 engages the cross feed. The slide panel is designed so that oil is delivered to the slide cylinder either from the high-pressure pump section, the flow from the low-pressure pump section being shut off, or from the low-pressure pump section with the flow from the high-pressure section being shut off.

The hydraulic panel for extending and clamping the tailstock quill consists of three separate housings which contain the following devices: check valves of the high- and low-pressure pump section, and the reducing valve in the first housing; reversing valve operated by two spring-centred pilot valves in the second housing; and the quill clamping valve and flow control valve for quill retraction in the third housing.

This hydraulic control panel, in conjunction with its pilot valves, has the following functions: (a) rapid advance of the tailstock spindle quill from the initial to the middle position; (b) quill advance from the middle position

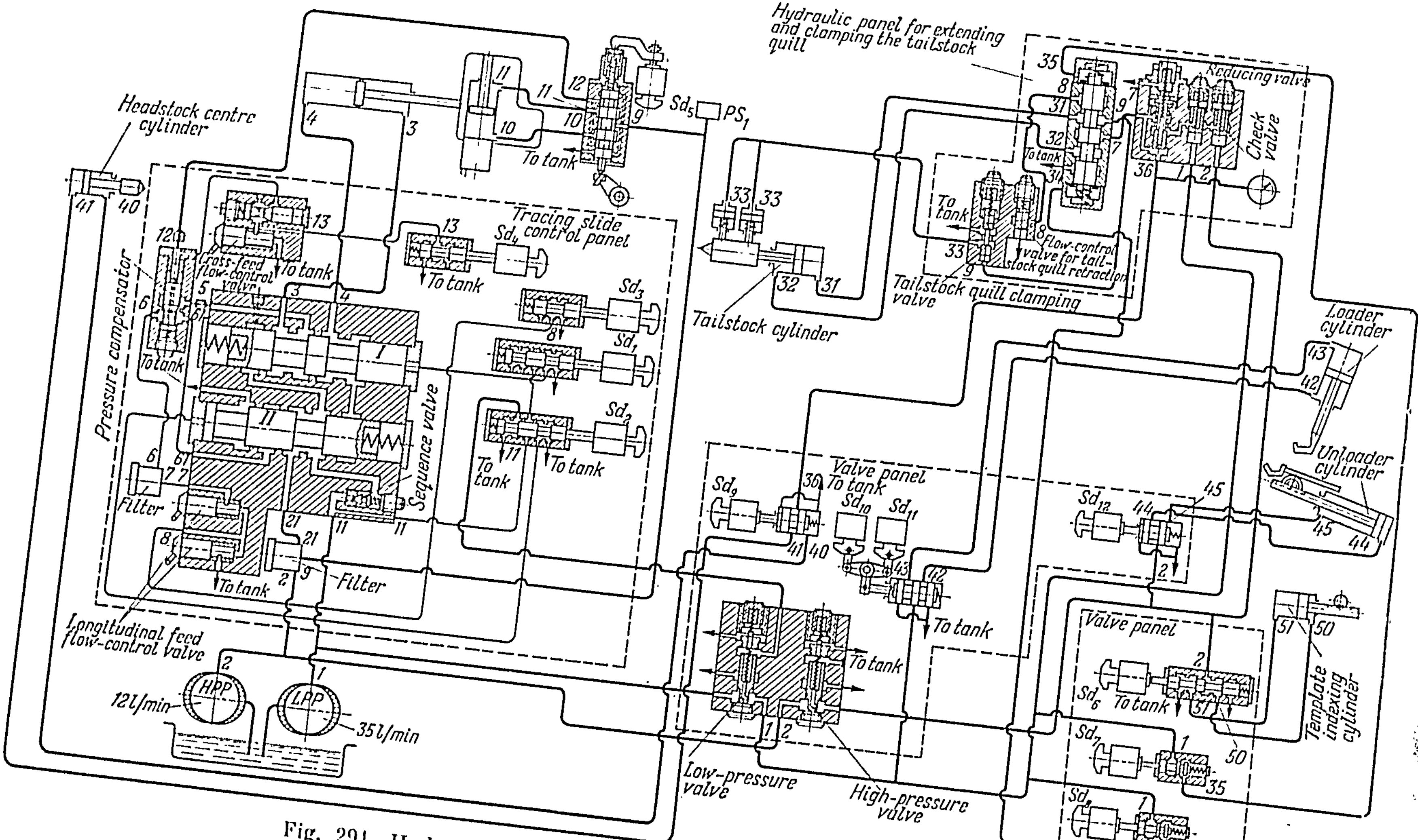


Fig. 291. Hydraulic circuit diagram of the model MP105 semiautomatic

up to the point where the work is clamped between the centres; (c) stopping and clamping of the quill; (d) unclamping of the quill and *its retraction* to the middle position; and (e) retraction of the quill from the middle to the initial position.

The two other panels mount pilot valves which control all motions in an automatic cycle, and the check valve for the high and low pressures.

At the beginning of an automatic cycle, the motor driving the hydraulic pump is switched on by pressing a push button (Table 49, operation element 1), and the mechanisms of the machine are set to the initial, or STOP, position (Table 49, element 2) using the manual (setting-up) controls. This position corresponds to the hydraulic circuit diagram as it is shown in *Fig. 291*.

In this case all the solenoids are de-energized and the directional valves *I* and *II* are shifted by their springs to the right and left positions, respectively, *in which the valve spools close off oil flow to the longitudinal* travel cylinder from the feed (low-pressure) pump section.

The tracer valve is in the neutral position and its spool shuts off oil flow *both to and from the valve. Oil from the feed pump drains back to the tank* through the high-pressure relief valve.

The sequence valve shuts off oil flow from the rapid-traverse (low-pressure) pump *section to the directional* valves, and the oil drains back to the tank.

The end of the longitudinal travel cylinder opposite to the one into which oil is to be admitted is closed and is under pressure, so as to avoid jumping of the carriage when the working feed is engaged.

All the subsequent operation elements proceed in the sequence shown in Table 49.

After the blank is fed between the centres and clamped and the loading member returns to its middle position (element *8*), selector switch *2LLS* (see Table 49) energizes solenoid Sd_7 (Fig. 292)* and oil is delivered from the low-pressure pump along pipeline *35* to the upper end of the reversing valve, shifting it downward.

The tailstock quill, together with the blank and headstock centre, advances toward the headstock until the end of the blank runs up against the serrations on the face of the driving centre *(element 9). At this, the pressure increases* in the supply system of the tailstock quill. Oil flowing along line *7* and through the grooves of the reversing valve spool passes through line *9* to *the quill clamping valve, compressing* its spring, and further through line *33* to the upper ends of the clamping cylinders. Upon this, the quill is firmly clamped.

*The following graphical symbols are used in Figs. 292 through 296. ▬▬▬ working circuit on travelling units; — — — working circuit on stationary units; ═══ drain circuit.

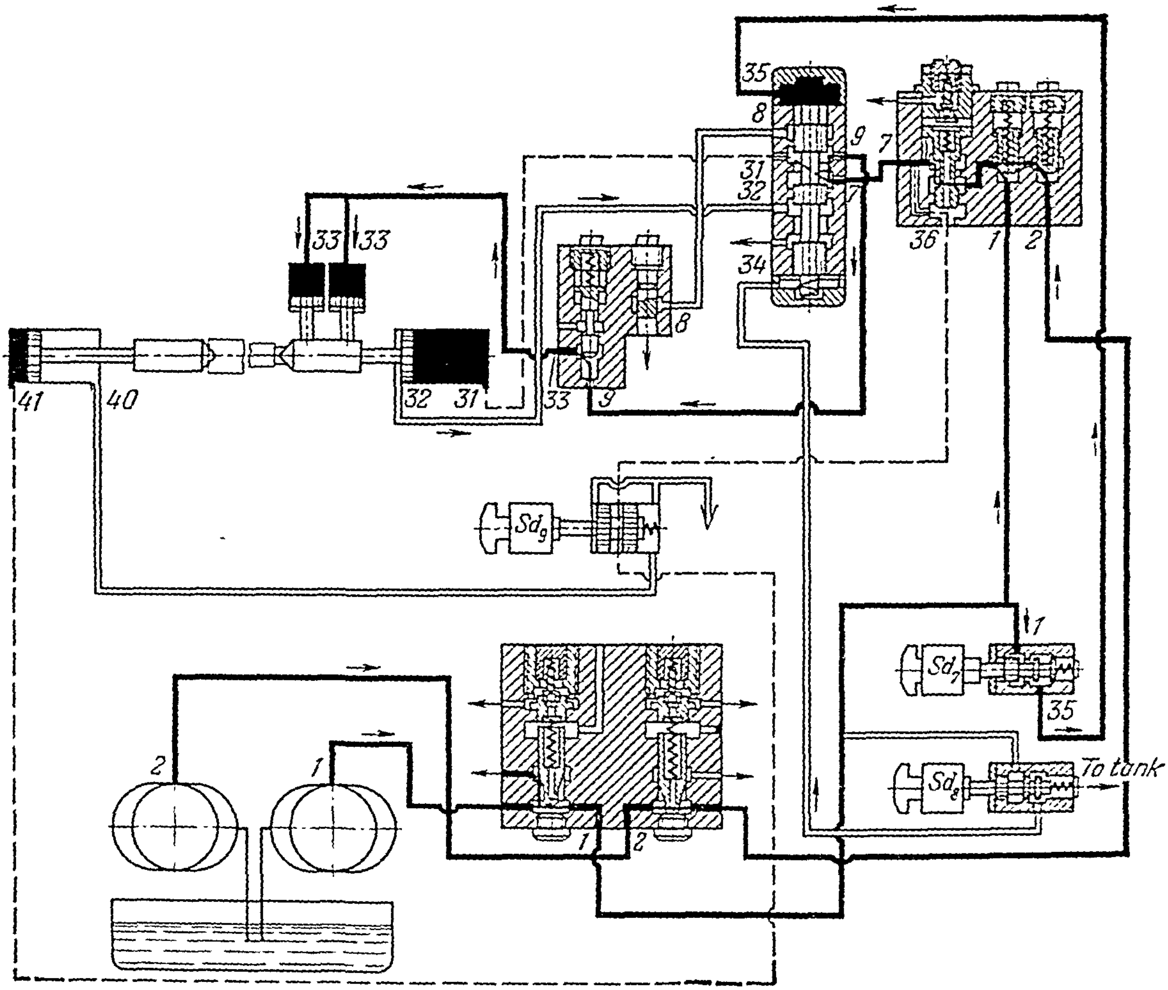


Fig. 292. Advance of the tailstock quill to a positive stop (work runs up against the headstock centre) and quill clamping (element 9, Table 49)

The clamping of the blank between the centres and the clamping of the quill are followed by rapid longitudinal and then rapid cross approach of the carriage and slide (elements 10a and 10c). This takes place in the following way. In its extreme forward position, the tailstock quill operates limit switch *3QLS* (Table 49), thereby energizing solenoids Sd_1 and Sd_2 (Fig. 293) and closing the magnetic starter to switch on the spindle drive motor.

Oil from the low-pressure pump section passes through the pilot valves operated by solenoids Sd_1 and Sd_2, and is admitted to directional valves *I* and *II* whose spools are shifted to the extreme left and right positions, res-

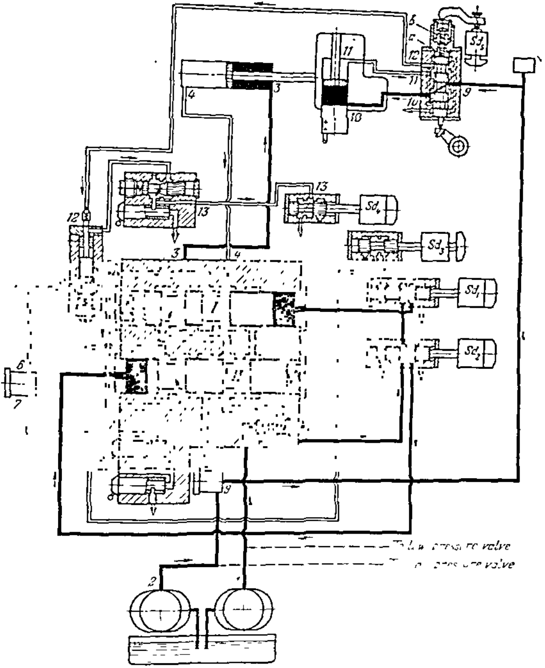


Fig. 293. Rapid longitudinal and cross approach of the tracing slide (elements 10a, b and c, Table 49)

pectively. Oil from the high-pressure pump section is blocked out of the panel since the middle land of the spool of directional valve *II* shuts the inlet port connected to line *21*. From the low-pressure pump section, oil flows through the sequence valve, grooves of the directional valves and along line *3* to the right end of the longitudinal travel cylinder. This effects rapid longitudinal approach of the carriage. From the left end of the longitudinal travel cylinder, oil flows along lines *4*, *5* and *6* and the groove of directional valve *II*, and is discharged to the tank.

During rapid longitudinal traverse, the cross slide occupies its extreme upper position.

At the end of the rapid longitudinal approach of the tracing carriage, limit switch *1LS* is operated (operation element 10c, Table 49). This switch energizes solenoids Sd_4 and Sd_5, and de-energizes solenoids Sd_1 and Sd_2.*

The springs of the directional valves shift their spools back to the previous STOP position. The lands of the directional valves block oil flow to and from the longitudinal travel cylinder so that its piston (and the carriage) will be stationary.

The energizing of solenoid Sd_5 releases the stylus valve spool and, under the action of spring *a*, the spool is shifted to its extreme lower position in reference to the housing of the stylus valve. This admits oil from the high-pressure pump section along lines *9* and *10* to the lower end of the cross slide cylinder. At this, the valve spool actuated by solenoid Sd_4 is in its left position where it permits oil to discharge from the other end of the cross slide cylinder, bypassing the cross-feed flow-control valve and thereby providing rapid cross slide approach. In this case, the oil flows from the cylinder along line *11*, a channel in the housing of the stylus valve, line *12*, the pressure compensator and line *13*.

Consequently, rapid approach of the tracing slide is controlled by the operating servomechanism, i.e., the slide is controlled by the hydraulic tracing stylus. If the stylus valve spool is in the lowered position in reference to its housing, the pressure switch is not subjected to high pressure and is therefore not actuated. The cross slide travels downward until the stylus reaches the template. This puts the valve spool in its neutral position in reference to the housing, blocking off oil flow to the cross slide cylinder, while oil under high pressure is admitted to the pressure switch (Fig. 294).

Upon being thus closed, the pressure switch transmits a signal for energizing the solenoids to carry out the tracing process.

The limit switch can be set up to provide the required sequence of feeds in each pass: either the first then second feed, or the second and then first feed, or only one feed, first or second.

*Operation elements 10a and 10c are combined in Fig. 293, and solenoids Sd_1 and Sd_2 are not shown in the de-energized position.

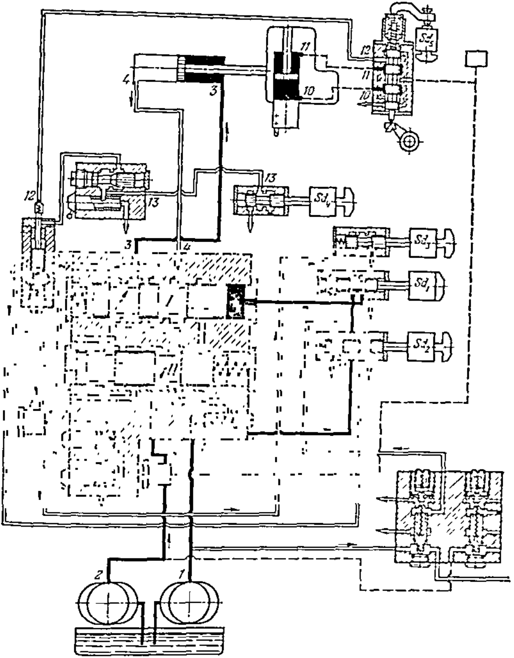


Fig. 294. Tracing (copy-turning) a cylindrical surface at the first rate of working feed (element 10d, Table 49)

Tracing (copy-turning) at the first rate of working feed (element 10d, Table 49) is effected with solenoid Sd_5 energized previously, and solenoid Sd_1 energized by the pressure switch. As solenoid Sd_1 is energized, the spool of directional valve *I* (Fig. 294) is shifted again to the left. The rapid traverse pump section discharges to the tank through the low-pressure valve, while oil from the high-pressure pump section closes the sequence valve and is admitted through grooves of the directional valves to the right end of the longitudinal cylinder. Oil from the high-pressure pump section also enters the stylus valve whose spool is in the neutral position. At this the flow-control valves and pressure compensator begin operation. They control the tracing slide position in accordance with the profile of the template (or workpiece).

The position shown in Fig. 294 corresponds to the turning of a cylindrical surface (the stylus valve spool is in the neutral position).

Oil passes from the left end of the longitudinal travel cylinder along lines *4* and *5*, through the pressure compensator, along lines *6* and *7*, through the first and bypasses the second longitudinal feed flow-control valve, along line *8* and through the valve of solenoid Sd_3 (now de-energized) to the tank.

Through grooves and line *12*, the discharge end of the stylus valve is connected to the pressure compensator and the cross-feed flow-control valve. During tracing operation, oil discharge is through this latter flow-control valve.

Therefore, this position differs from the position for rapid crosswise approach in that solenoid Sd_4 is de-energized and the spool of the valve it actuates blocks free discharge of oil to the tank.

Tracing (copy-turning) at the second rate of working feed is effected with solenoids Sd_1, Sd_3 and Sd_5 (Table 49), in the energized position. The operation of the hydraulic drive is similar to tracing at the first rate of feed, except that when solenoid Sd_3 is energized (Fig. 295) its valve blocks oil discharge to the tank. As a result, oil from the first flow-control valve passes as well through the second flow-control valve before it is discharged to the tank.

A command signal for rapid withdrawal of the cross slide is transmitted by limit switch *4LS* (operation element 10e, Table 49) at the end of the cut, or pass. This de-energizes solenoids Sd_1 and Sd_5 (Fig. 296), and energizes solenoid Sd_4. When solenoid Sd_5 is de-energized, spring *b* shifts the stylus valve spool to the upper position, compressing spring *a*.

From the high-pressure pump oil is delivered along lines *9* and *11* to the upper end of the cross slide cylinder. The energizing of solenoid Sd_4 again opens free oil discharge from the lower end of the cross slide cylinder, bypassing the cross-feed flow-control valve. At this the cross slide traverses rapidly upward. Simultaneously with withdrawal of the cross slide, the main drive motor is switched off. The automatic cycle continues further according to whether the operation is to be done in one or in two passes. In the latter case, the corresponding operation elements are to be repeated.

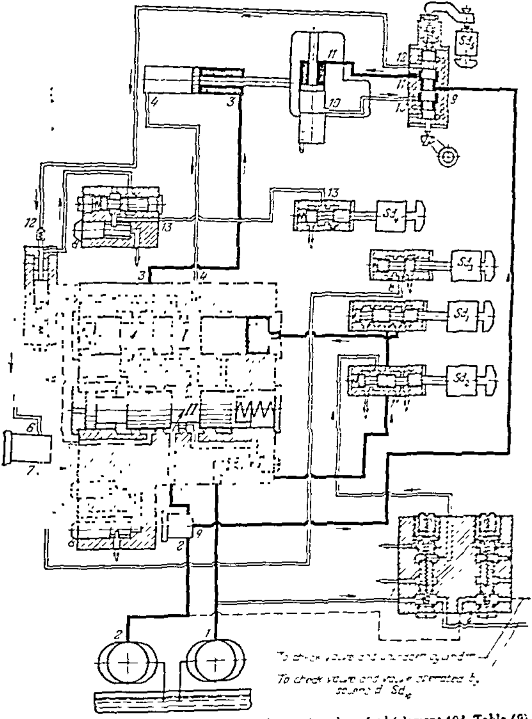


Fig. 295. Tracing (copy-turning) at the second rate of working feed (element 10d, Table 49)

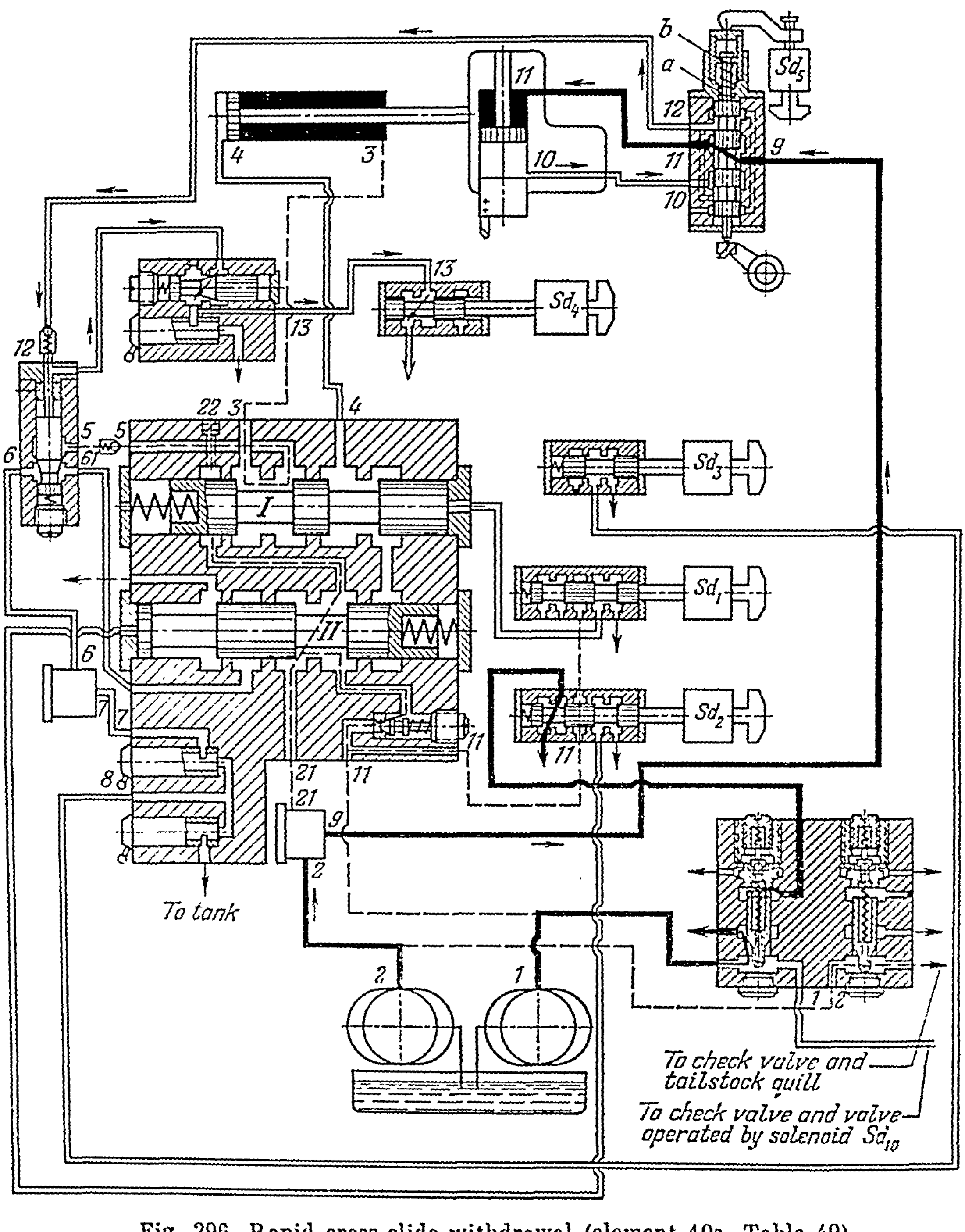


Fig. 296. Rapid cross slide withdrawal (element 10c, Table 49)

CHAPTER 17
SPECIAL AND SPECIALIZED MILLING MACHINES

17-1. Machines for Milling Drill Flutes and Body Diameter Clearances

Milling machines for making the flutes and body diameter clearances of twist drills are of considerable importance in tool production since these operations are very critical in several aspects and require a high labour input. In accordance with the volume of production, these operations can be performed in universal milling machines or in special automatic or semiautomatic machines.

The flutes and the body diameter clearances are milled separately in a universal milling machine. The application of special multiple-piece fixtures for milling drill flutes in a universal milling machine leads to a substantial increase in the output of this operation.

Special automatic or semiautomatic milling machines are employed for this operation in large-lot and mass production.

Existing models of special milling machines designed for this purpose operate by one of the following ways:

(1) milling one flute and one body diameter clearance simultaneously;

(2) milling two flutes simultaneously, followed by two body diameter clearances;

(3) milling the flutes separately, then milling two body diameter clearances simultaneously;

(4) milling both flutes and both body diameter clearances simultaneously.

Milling machines operating by the second method possess one important shortcoming: the flutes milled on the drill may not be symmetrical to the drill axis due to insufficiently accurate setting of the milling cutters.

Machines which mill one flute together with one body diameter clearance do not have this shortcoming The location of the flutes in this case depends only upon the indexing mechanism which, as a rule, ensures the required accuracy. In this method, however, it is impossible to provide for the most expedient speeds and feeds for the two form cutters which operate under quite different conditions The rate of feed is selected to suit the fluting cutter since it is subject to the higher load. Feed selected on this basis is comparatively low for the cutter that mills the body diameter clearance since it operates with a relatively shallow depth of cut

The method of milling two flutes simultaneously and then two body diameter clearances simultaneously does not have this last drawback; feed can be selected to suit the depth of cut for each operation so that milling can be done more efficiently.

The third method listed above, in which the flutes are milled separately and then the body diameter clearances are milled simultaneously, excludes all of the previously mentioned drawbacks. The construction of the machine and the setting up of the cutters are considerably simplified in this case.

The most widely employed milling machines in twist drill production are special automatic or semiautomatic machines which mill one flute and one body diameter clearance simultaneously, after which the drill blank is indexed.

17-2. Semiautomatic Drill-Flute Milling Machine, Model 6793У

Purpose, Gear Trains and Construction

Model 6793У is a special semiautomatic machine for milling the flutes and body diameter clearances of twist drills from 24 to 40 mm in diameter and with a helix angle from 20° to 33°. One flute and one body diameter clearance are milled simultaneously. After indexing the blank through 180°, the same operations are repeated for the second land of the drill. The maximum length that can be milled is 400 mm.

Two form milling cutters are used: one for the flute and the other for the body diameter clearance. The process of milling each flute together with its body diameter clearance consists of three operation elements: rapid approach of the blank to the cutters, working feed of the blank and rapid withdrawal. In addition to its straight-line motion, the blank is also rotated so that milling is carried out along a helix.

When the first land has been milled the blank approaches the cutters for milling the second land after being indexed through 180°. When the second land has been completed, the machine stops automatically.

Each cutter is driven and the working feed and rapid traverse motions are effected by separate electric motors which are switched on and off in accordance with the given processing procedure by limit switches (in-travel controls).

The cutters are advanced and withdrawn from the blank hydraulically.

A general view of this flute milling machine is shown in Fig. 297.

Base *5* of the machine is a rigid casting of rectangular shape. Bed *1* is mounted and secured on special machined pads on top of the base. Spindle, or work, head *2* travels along ways at the left end of the bed. At the right

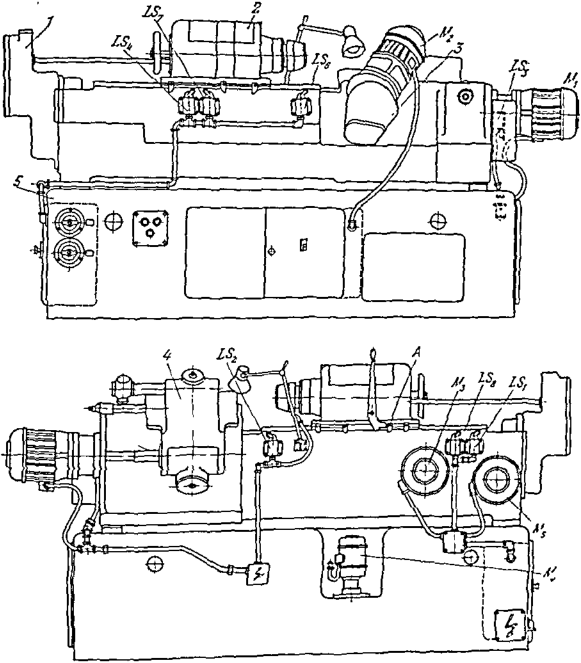


Fig. 297. Semiautomatic drill-flute milling machine, model 6793У

end the flute and clearance milling heads (*3* and *4*, respectively) are arranged, as well as the hydraulic pump and cylinder.

The gearbox is mounted on the left end, and the screws for traversing the spindle head are mounted inside the bed.

The fluting cutter is driven (Fig. 298) by flange-type motor M_2 (1 kW, 950 rpm) mounted directly on the milling head housing. Cutter speeds can be varied by change gears in a range from 82 to 185 rpm.

Rotation is transmitted from flange-mounted motor M_1 (1 kW, 950 rpm) through worm gearing $\frac{5}{22}$ to the spindle of the clearance milling cutter and, simultaneously, through a silent chain, to spur-gear pump *6*.

Working feed of the spindle head is powered by flange-mounted motor M_3 (1 kW, 950 rpm) through gears $\frac{22}{52}$, feed change gears $\frac{a}{b}$, worm gearing $\frac{1}{38}$, bevel gears of the differential gearing $\frac{30}{30}$, gearing $\frac{37}{62} \times \frac{62}{74}$ to the lead screw with R.H. thread and a pitch of $t = 8$ mm.

Electric motor M_5 (1.7 kW, 1,470 rpm) powers the rapid approach and withdrawal motions of the work head. In this case, the lead screw is driven by this motor through worm gearing $\frac{2}{26}$, the differential $\left(\text{gearing ratio } \frac{2}{1}\right)$ and the gearing $\frac{37}{62} \times \frac{62}{74}$.

Since the drill flute is milled along a helix, the work spindle is rotated during its travel from the lead screw drive through the gearing $\frac{28}{C} \times \frac{24}{48}$ (where C is the number of teeth on the change gear) and the herringbone gears $\frac{24}{96}$.

The flute and clearance milling heads have a rocking motion that enables them to be set to the depth of cut before the working feed begins and to be retracted from the machined surfaces during the rapid return traverse of the spindle head.

The heads are set to their working position by pulling them downward. This rocking motion is effected by cams mounted on shaft *I*, which is rotated periodically by a hydraulic cylinder through a rack-and-pinion drive. The left-hand cam actuates the roller of rocker-arm *10*. The latter is linked through tie-rod *4* with the flute milling head which it swings downward. The right-hand cam actuates the roller of rocker-arm *8*. This moves tie-rod *5* which is hinged to gear rack *3*. The latter, in its motion, rotates a double gear which meshes with and shifts rack *2*. This last rack is hinged to the clearance milling head. The two heads are returned to their initial upper position by spring action.

The web of the drill is tapered (to increase its strength) by an amount equal to 1.4 mm per 100 mm of length. This taper is obtained by gradually

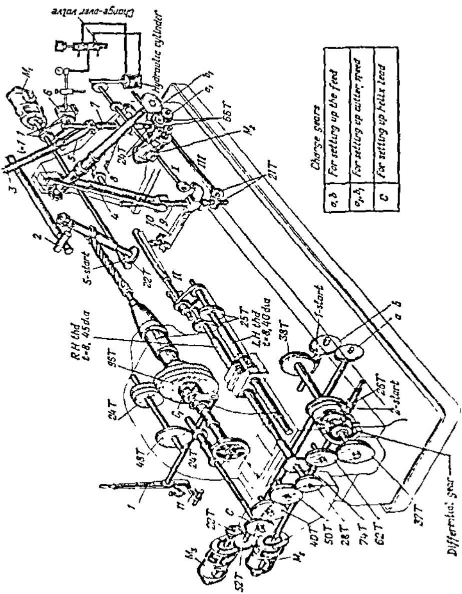


Fig. 293 Gearing diagram of the model 6703У milling machine

raising the flute milling cutter in the course of its operation. For this purpose a nut is rotated from the second screw through a chain drive. The threaded end of shaft *II* screws into the nut so that the shaft travels axially. Secured on the other end of this shaft is a wedge against which another roller of rocker-arm *10* bears. The height of the wedge is reduced toward the right end of shaft *II* so that rocker-arm *10* is raised by the spring as the shaft moves to the left. The milling head, together with tie-rod *4*, is gradually raised by spring action and, as a result, a tapered web is milled in the drill.

It is also possible to retract the milling heads from the work manually by turning shaft *III* with a crank handle. This rotates screws *9* and *7* through the spiral gears, leading to movement of rocker-arms *4* and *5* and hence raising the milling heads.

The machine is operated as follows. Upon pressing the START push button (*2PB*, Fig. 299), motors M_1 and M_2 (Figs. 298 and 299) are switched on, as is the motor of the hydraulic system pump. At the same time, motor M_5 is switched on and it rapidly advances the work head from its extreme rear position to the initial working position. The START push button is held down until dog *A* (Fig. 297) releases the lever of limit switch LS_8 (Figs. 297 and 299) which serves to stop the machine after the drill blank is machined.

At the end of the rapid approach of the work head, an adjustable dog, arranged in front, operates limit switch LS_4 (Fig. 299). This switches off the rapid traverse motor M_5 (Figs. 298 and 299). At the same time, the solenoid of the valve for changing over the hydraulic system is de-energized. A rack, linked to the piston rod of a hydraulic cylinder, is actuated. It turns a gear and, consequently, a shaft with plate cams. The latter, through appropriate lever systems, advance the cutters to the blank, i.e., to the working position. This motion releases the lever of limit switch LS_3 by means of which the working feed motor M_3 and the coolant pump motor M_4 are switched on.

At the end of the working feed, a dog operates limit switch LS_6 and these motors are switched off. At the same time, the solenoid of the change-over valve is energized, the cutters are withdrawn from the work, limit switch LS_3 is operated again, and rapid traverse motor M_5 is switched on. The work head is rapidly withdrawn to its initial position.

Indexing of the work through 180° takes place during this rapid withdrawal of the work head. To accomplish indexing, the gear train linking work head travel with spindle rotation is disengaged in the following manner.

The shaft of the fork for controlling clutch C_1 (Fig. 298) is brought out at the rear of the work head, and lever *1* with a handle is mounted on its other end. Upon work head withdrawal, a lug of this lever runs up against stop *11*. This turns the lever and clutch C_1 is disengaged from herringbone gear $96T$. Thus, the work ceases to revolve even though the work head continues to

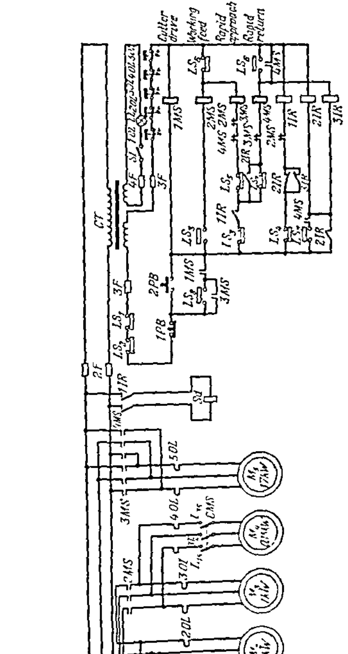


Fig. 299. Elementary diagram of the electric circuit in the model 6703V milling machine

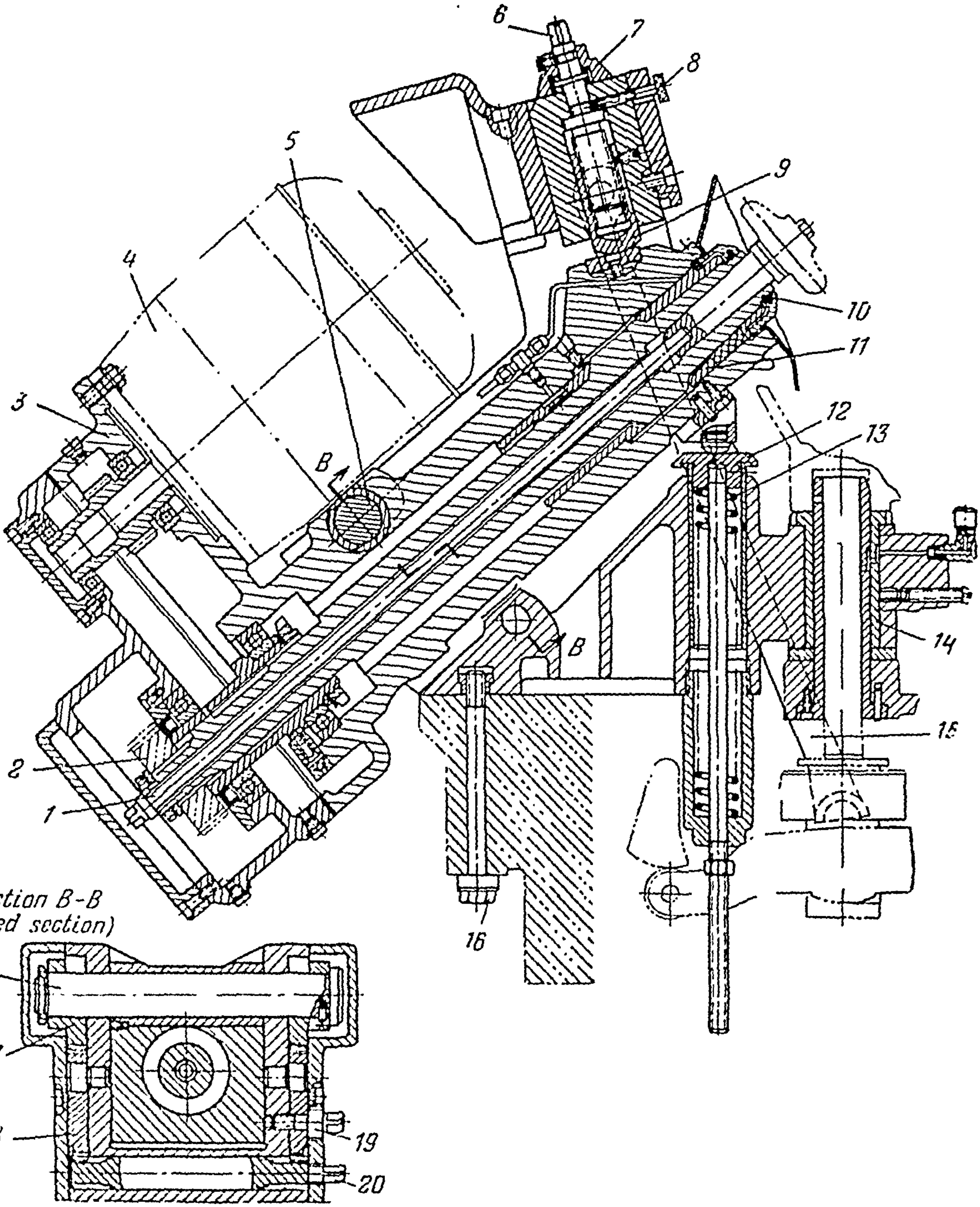


Fig. 300. Flute milling head of the semiautomatic milling machine:

1—draw-in bolt; 2—change gear; 3—head housing; 4—flange-mounted electric motor (1 kW, 950 rpm); 5—pivot of the head housing; 6—screw for setting the cutter to the flute depth; 7—dial showing the amount of cutter adjustment; 8—screw for clamping the dial; 9—stop; 10—flute cutter spindle; 11—spindle bearing; 12—spring-loaded stop; 13—spring for raising the milling head; 14—eccentric sleeve for setting the cutter in reference to the blank axis; 15—tie-rod for raising the head; 16—screw for clamping the head; 17 and 18—segment gears for tilting the head; 19—screw for clamping the head; 20—shaft with integral pinions for tilting the head

travel to the left (withdrawal). Lever *1* continues to turn until its screw swings stop *11* downward. This releases lever *1* and a spring forces clutch C_1 back into engagement with herringbone gear 96*T*. Engagement occurs after the gear has turned through 180° since the gear and clutch C_1 each has only two teeth.

At the end of the rapid withdrawal motion (at the point of the initial working position), a dog operates limit switch LS_7 to switch off rapid traverse motor M_5. After this, the cutters approach the work, and the working feed motor M_3 and the coolant pump motor M_4 are switched on. Due to the 180° lag in spindle rotation in the helical motion gear train, the work turns out to be indexed through 180°, in reference to the first pass, when it approaches the cutters again.

The cutters now begin to mill the second flute and body diameter clearance.

At the end of the second working stroke, when limit switch LS_6 energizes the solenoid of the change-over valve and the cutters are withdrawn from the work, the work head is withdrawn to its extreme left initial position where its positive stop operates limit switch LS_8 and all motors of the machine are switched off. Then the operator removes the milled drill blank and mounts a new blank. The cycle is repeated by pressing the START push button again. Emergency limit switches LS_1 and LS_2 are provided as a safety measure to restrict work head travel at the extreme positions. Emergency limit switch LS_5 limits rapid approach of the head.

The flute milling head (Fig. 300) is mounted at the front of the base on a specially machined pad. Its main parts—the upright and the housing—are made of cast iron.

The assembled housing is pivoted on an axle between the cheeks of the upright.

Screw *6* with dial *7* enables the flute to be milled to the required depth with a high degree of accuracy.

The clearance milling head (Fig. 301) is located on inclined ways at the rear part of the base.

The head can be adjusted together with the upper housing to vary the width of the margins in milling the body diameter clearances. The depth of the clearance can be set up to suit the size of drill being manufactured by means of screw *4* and dial *5* mounted on the screw.

The spindle, or work, head (Fig. 302) travels along a dovetail way in which excess clearance is taken up by adjusting taper gib *12*.

The rear guide *11* is of the removable type to allow the work head to be mounted on the base way from above.

A nut providing for longitudinal travel of the work head is secured underneath.

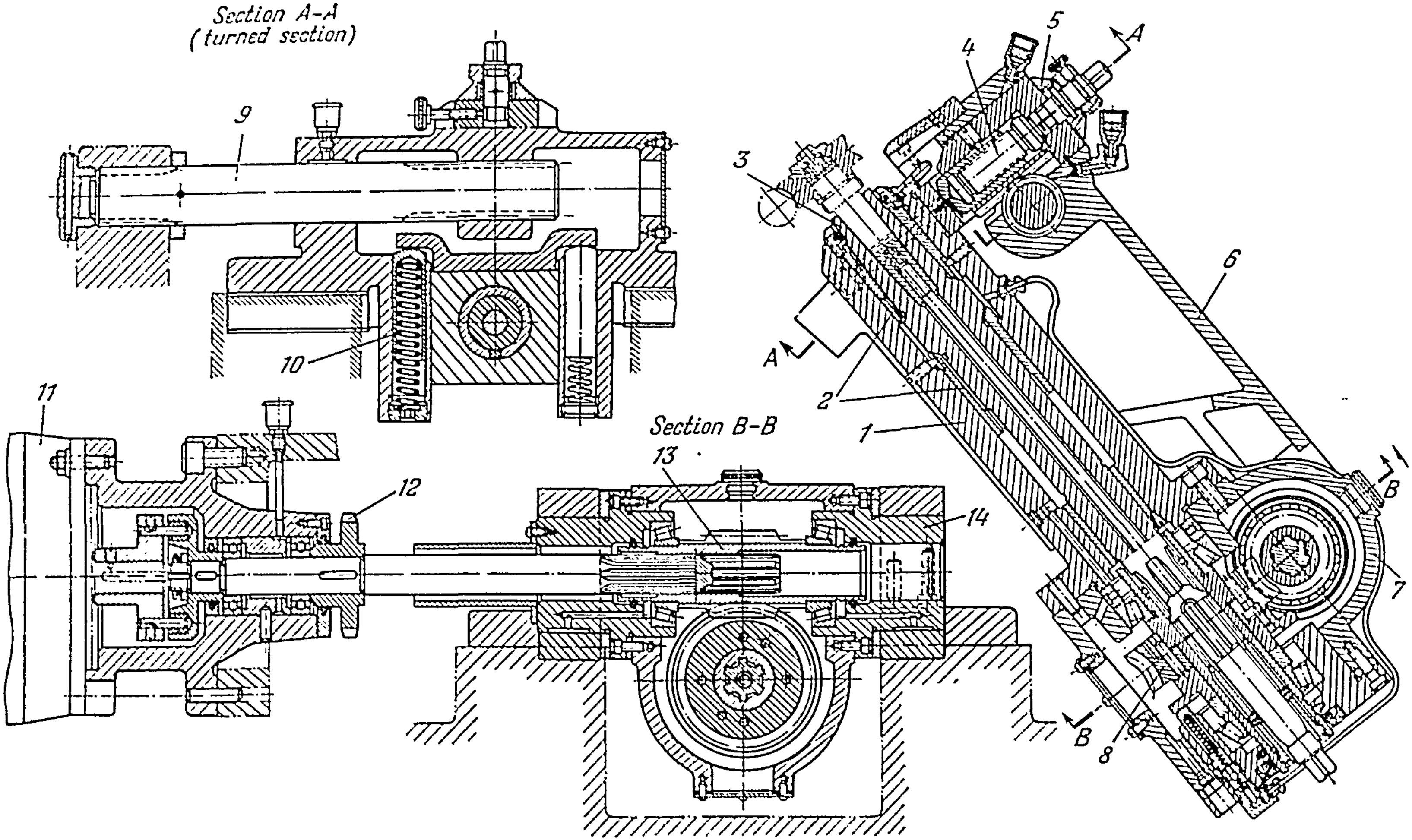


Fig. 301. Clearance milling head of the semiautomatic milling machine:

1—spindle housing; *2*—spindle bearings; *3*—clearance cutter spindle; *4*—screw for setting the cutter to the depth of the body diameter clearance; *5*—dial showing the amount of cutter adjustment; *6*—head housing; *7*—housing of the worm gearing drive with trunnions *14*; *8*—worm wheel; *9*—pinion shaft meshing with the rack for rocking the head; *10*—spring for raising the milling head; *11*—flange-mounted electric motor (1 kW, 950 rpm); *12*—drive sprocket of the hydraulic pump; *13*—worm; *14*—trunnions on which the head rocks

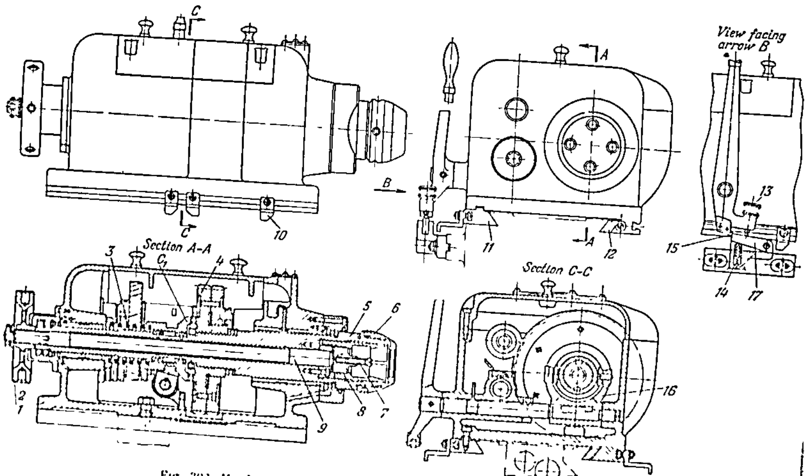


Fig 302 Headstock of the model 6793У semiautomatic milling machine:

1 headstock housing 2 handwheel for clamping the blank; 3—spring for engaging the clutch, 4—herringbone drive gear; 5 spindle 6 thrust nut of the clamping collet, 7—stop for setting the drill blank, 8—guide bushing; 9—collet tie-rod, 10 dogs for changing over operation elements, 11—removable gear guide; 12—taper gib for adjusting the clearance in the guides 13 screw for regulating the moment of clutch engagement, 14—stop bar spring; 15—lug of the lever (for lever rotation), 16 fork for disengaging the clutch, 17—stop bar, C_1—two-tooth clutch

Setting Up the Milling Machine

The model 6793У semiautomatic milling machine is set up to data obtained by means of the following formulas (see Fig. 298).

Setting up the lead of the flute helix

$$P=\frac{96}{24}\times\frac{48}{24}\times\frac{C}{28}\,t\ \text{mm}$$

where P = lead of the flute helix, mm
t = pitch of the lead screw, mm.

After substituting the value of the lead screw pitch (t = 8 mm), we obtain

$$P=\frac{16C}{7}\ \text{mm}$$

Then, solving for the number of teeth of the change gear

$$C=\frac{7}{16}P=0.437P$$

Since the lead P (mm) is related to the drill diameter d (mm) and the flute helix angle ω by the formula

$$P=\pi d\cot\omega$$

then

$$C=\frac{7\pi}{16}d\cot\omega\cong 1.37d\cot\omega$$

Setting up the feed. In setting up the gear train for the feed motion, i.e., the rate of feed of the work past the cutters, a certain feed per cutter tooth s_z is assigned. Then the feed per minute is

$$s_m=s_z z n_c$$

where the number of teeth z of the cutter and its speed n_c in rpm are known.

Since the feed per minute is determined by the relationship

$$s_m=\frac{\pi d n_b}{\sin\omega}$$

where n_b = speed of work rotation, rpm
$\frac{\pi d}{\sin\omega}$ = developed length of the flute per revolution of the blank,
the required work speed is found from the formula

$$n_b=\frac{s_m\sin\omega}{\pi d}\ \left(\text{or}\ n_b=\frac{s_z z n_c\sin\omega}{\pi d}\right)$$

The feed gear train equation for model 6793У (see Fig. 298) is

$$n_b=950\times\frac{22}{52}\times\frac{a}{b}\times\frac{1}{38}\times\frac{37}{74}\times\frac{28}{C}\times\frac{24}{48}\times\frac{24}{96}=\frac{73{,}150}{3{,}952}\times\frac{a}{b}\times\frac{1}{C}$$

Then, substituting

$$n_b = \frac{s_m \sin\omega}{\pi d} \text{ and } C = \frac{7\pi}{16} d \cot\omega$$

we obtain

$$\frac{s_m \sin\omega}{\pi d} = \frac{73,150}{3,952} \times \frac{a}{b} \times \frac{16 \tan\omega}{7\pi d} = \frac{42.3 \tan\omega}{\pi d} \times \frac{a}{b}$$

from which

$$\frac{a}{b} = \frac{s_m \cos\omega}{42.3}$$

where a and b are the numbers of teeth on the feed change gears.

17-3. Semiautomatic Tap-Flute Milling Machine, Model 6B-1M

Purpose and Construction

This machine is intended for milling straight flutes on taps of all types listed in the USSR standards in a size range from 10 to 50 mm (metric thd), for milling straight-flute hand and machine reamers, with regular or irregular spacing in a range from 10 to 46 mm, as well as the slots for blades in the bodies of inserted-blade milling cutters in a range from 75 to 150 mm in diameter.

The version of model 6B-1M intended for milling tap flutes is to be considered below.

Model 6B-1M (Fig. 303) is a hydraulic 8-position semiautomatic milling machine and is designed for milling straight flutes with regular or irregular spacing on taps and other tools.

The working feed and rapid table withdrawal, cutter advance to the working position and retraction at the end of the operation, indexing and clamping of the blank are all accomplished by hydraulic means.

The machine consists of the following main units: base, table, milling head, headstock and tailstock, coolant system, hydraulic power unit and electrical equipment.

Data on this machine are given in the following specifications.

Brief Specifications of Semiautomatic Milling Machine, Model 6B-1M

Ranges of sizes of taps milled (metric thd)	
lower range	M10 to M24
upper range	M24 to M60
Length of taps accommodated, mm	60 to 380
Maximum length milled, mm	200

Number of flutes milled on tool blanks:	
minimum	3
maximum	25
Number of blanks milled simultaneously	4* to 8
Spindle speeds, rpm	250 and 300
Working feeds of the table, mm per min	15 to 500
Speed of rapid table withdrawal, mm per min	1,300
Power of main drive motor, kW	4.5 or 7**

*In the size range from 40 to 60 mm, 4 tap blanks are milled simultaneously. Special spacers must be put between the centres of the free spindle quills to ensure proper operation of the hydraulic system.

**The 7-kW motor is installed on machines which are to handle the upper size range (M24 to M60).

The cutters are retracted from the machine surface by a rocking motion of the milling head with the cutters. Bosses provided for this purpose on the head have pins fitted in their holes with a force fit. These pins pivot in the holes of an upright rigidly secured on the base.

Mounted on the top surface of the milling head housing is a rigid overarm on whose front end a boss with a trunnion is provided. The axis of the trunnion coincides with the axis about which the milling head rocks.

The trunnion enters a hole in a bracket mounted on a pad on the front wall of the base. The push-button control panel is mounted on the front surface of this bracket. A dovetail guide underneath the overarm carries an intermediate support for preventing bending of the cutter arbor, and an end support in which an antifriction bearing is mounted for holding the second end of the arbor.

This construction possesses sufficiently high rigidity for the operations that are performed.

The spindle of the milling head runs in roller bearings and is powered directly from an electric motor through a V-belt drive.

The spindle speeds indicated in the specifications are obtained by means of a change pulley installed on the motor shaft.

The depth of cut is set by turning handwheel *6* (Fig. 304*a*) using the scale on thimble *7* graduated in 0.05-mm divisions. The end of screw *9* bears on spherical washer *13* which lies in the recess of stop *14*. The latter is press-fitted into upright *15* which is fastened to the base.

Lever *10* with ball click *11* serves to lock the screw in the set-up position.

The milling head is raised and lowered by hydraulic means (Fig. 304*b*). This is accomplished by hydraulic cylinder *16*, secured to the base, whose piston *17* imparts a rocking motion to the milling head housing through rod *18* and link *19*.

Base *3* of the machine (see Fig. 303) is a hollow box-shaped casting with a top plate for mounting the milling head upright *5* and the motor base.

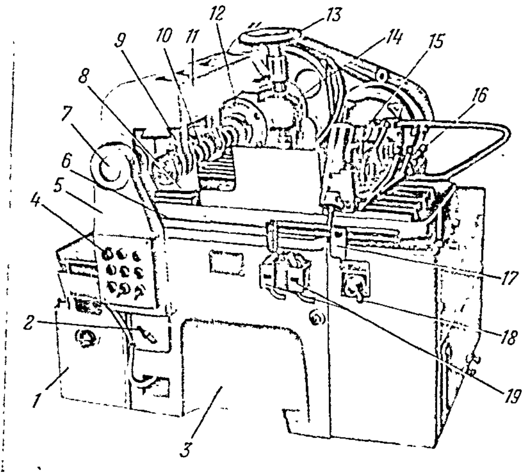


Fig. 303. Semiautomatic tap-flute milling machine, model [6B-1M

1—coolant tank, 2—main line switch 3— [illegible]
6—table, 7—milling head pivot pin 8—t [illegible]
arm, 12—milling head 13—handwheel [illegible]
setting, 15—headstock (indexing head) [illegible]
the milling length [illegible]

Table 6 travels along the dovetail guide of the base The flange of the table feed hydraulic cylinder and the tank of the pumping unit are secured to the right end of the base, the coolant tank is secured to the left end

The electrical equipment panel is housed in the rear cavity of the base.

The top surface of table 6 has a pad for fastening the tailstock, and T-slots for securing the headstock, or indexing head The tailstock has eight

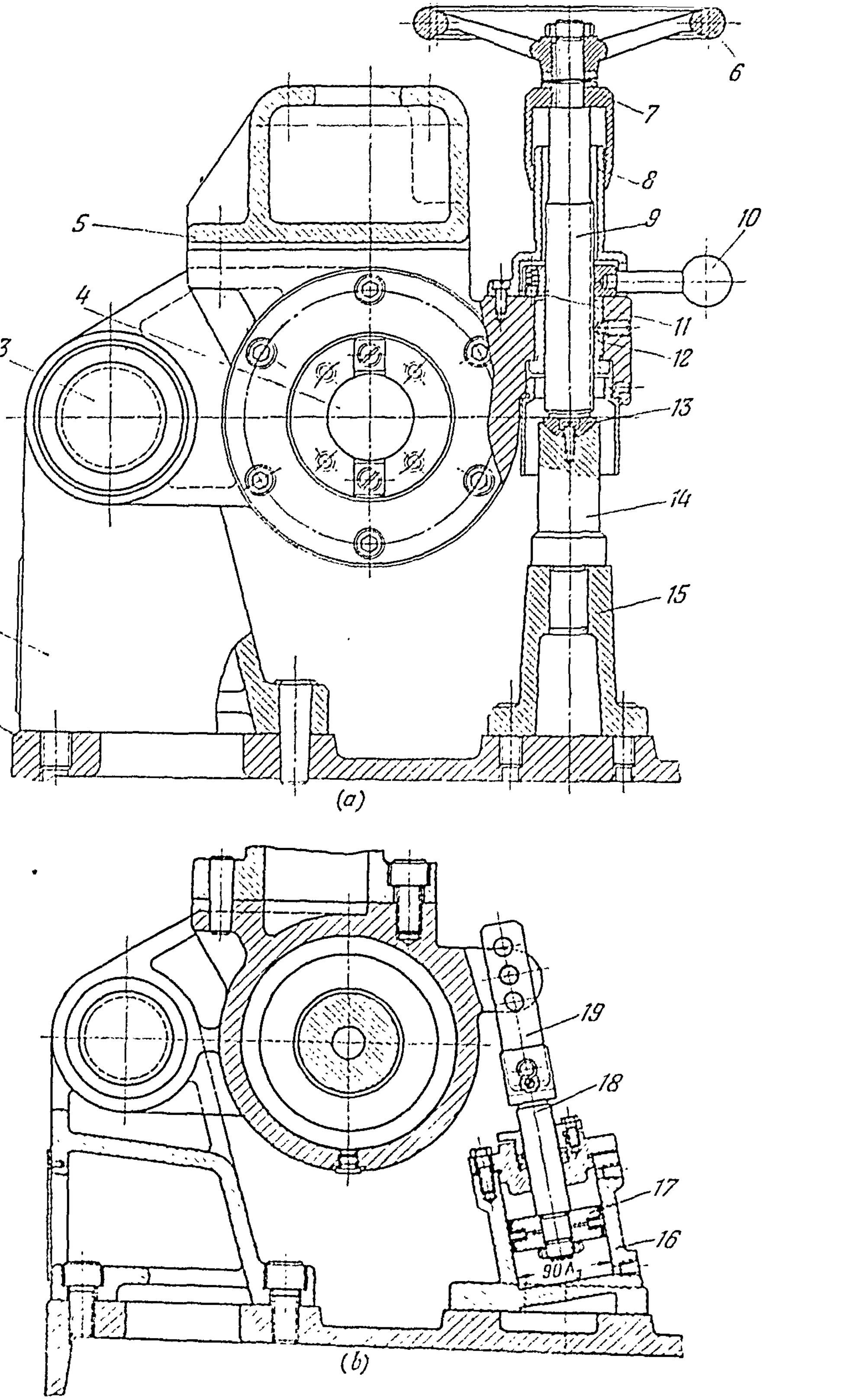


Fig. 304. Milling head of the model 6B-1M milling machine:

1—base; *2*—milling head upright; *3*—milling head pivot pin; *4*—cutter spindle; *5*—overarm; *6*—handwheel for setting the depth of cut; *7*—thimble; *8*—thimble sleeve; *9*—screw for setting the depth of cut; *10*—lever for locking the depth setting; *11*—ball click; *12*—nut; *13*—spherical washer; *14*—stop; *15*—upright of the stop; *16*—hydraulic cylinder; *17*—piston; *18*—rod; *19*—link

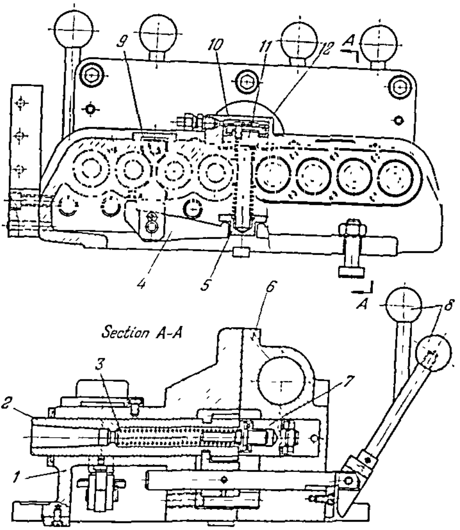


Fig. 305. Headstock of the model 6B 1M semiautomatic milling machine

centres (as has the headstock) and is rigidly secured on the pad of the table. The headstock can be adjusted along the table to suit the length of the taps being milled.

Eight quills *2* (Fig. 305), on which integral gear teeth have been cut, can be extended or retracted in bores of headstock housing *1*. The quills fit in the bores with a slide fit. The gears of the sets of four quills on each side are

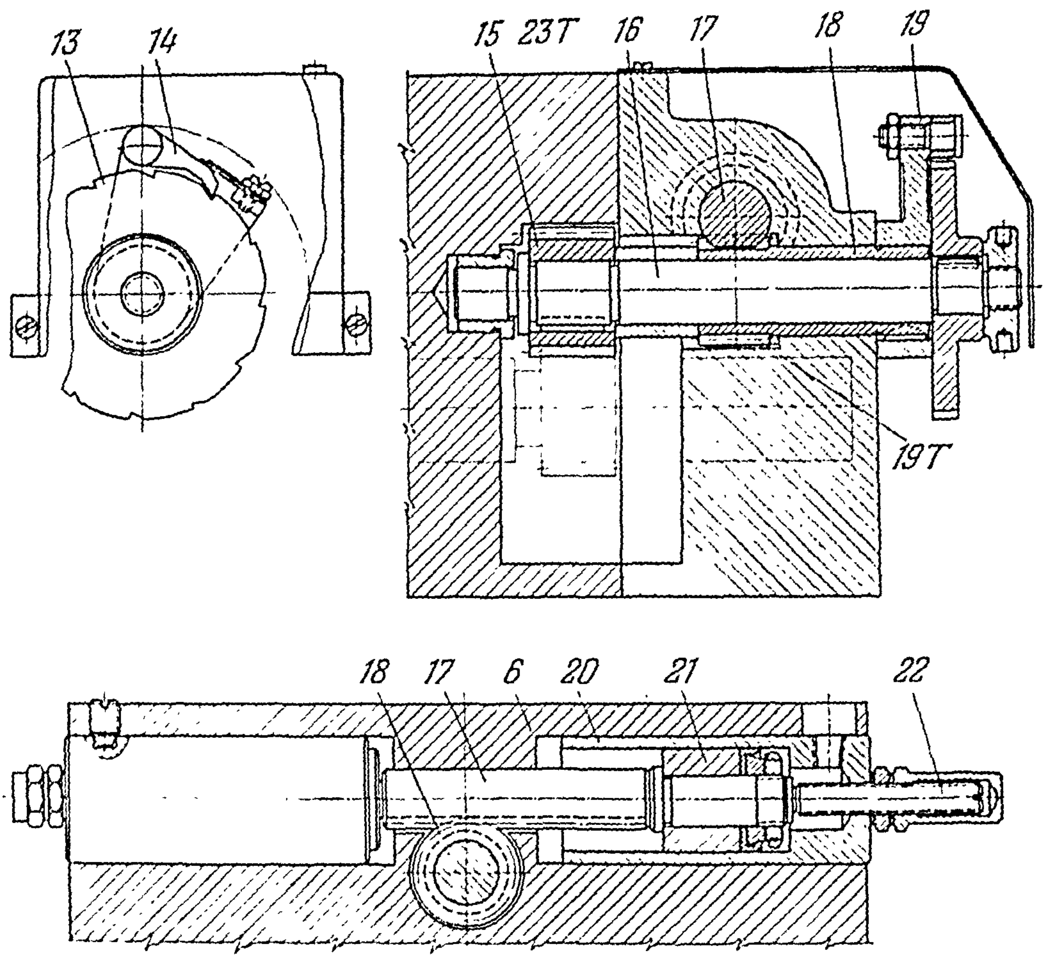


Fig. 306. Indexing mechanism

constantly in mesh and can be turned by gear *15* (Fig. 306) of the indexing mechanism, arranged in the central part of the headstock.

Indexing is carried out in the following manner. Two pistons *21*, arranged in blind-bore cylinders *20* that are secured in bores of housing *6* (Figs. 305 and 306), shift rack *17*. This rack meshes with pinion *18*. Lever *19*, carrying pawl *14*, is keyed on the hollow shank of the pinion. When rack *17* is shifted, pawl *14* turns index plate *13*. This plate is mounted on shaft *16* of central driving gear *15* which transmits the indexing motion to the headstock quills.

The machine is set up to mill the required number of flutes by means of indexing plate *13* whose rotation is limited by the travel of pistons *21* to

positive stops *22*. These stops can be adjusted to ensure accurate indexing. The provision of spare travel in the retraction of pawl *14* enables flutes with irregular spacing to be obtained if the corresponding indexing plates are used.

Driving devices with a square socket accommodating the square of the tap are inserted in the taper holes of the quills. This feature locates the tap blank in reference to the quill. The quills are held in the extended position by the action of springs *3* (Fig. 305). During the working feed, they are held by oil pressure. This is accomplished by pistons *7* which are mounted in bores of rear housing *6*. These pistons bear against the end faces of the gears on quills *2*. The quills are retracted for mounting the blanks and removing the milled workpieces by individual levers *8*.

Hydraulic cylinder *10* is mounted on the top surface of housing *1*. The force exerted by piston *12* of this cylinder is transmitted through rod *11* and the flange of thrust bushing *5* to levers *4*. By means of links *9* these levers clamp the two middle quills in each group of four.

Eight tap blanks up to 40 mm in diameter are milled simultaneously by eight fluting cutters mounted in a gang on the milling arbor. Taps from 40 to 60 mm in size are milled four at a time. In this case, spacers must be put between the centres of the free quills.

After the milled workpieces are removed, new blanks are loaded and the machine is started on the automatic cycle, the following operations are performed: unclamping and indexing the quills, advancing and clamping the quills, lowering the cutters, working feed, raising the cutters and rapid return of the table. Then the cycle is repeated.

Hydraulic Circuit of the Milling Machine (Fig. 307)

The functions of the hydraulic circuit include working feed and rapid traverse of the table, lowering (approach) and raising (withdrawal) of the milling head, indexing and clamping of the headstock quills.

Vane pump *1* (type Л1Ф-12) delivers oil through plate filter *2* to the hydraulic system. The pump is powered by a 1-kW electric motor running at 950 rpm.

The maximum pressure in the system is limited by balanced-piston relief valve *4*. The normal pressure is 18 kg per sq cm. In making adjustments, the pressure in the hydraulic system is checked on pressure gauge *3*. After setting the operating pressure the gauge is shut off by means of a shut-off valve built into the pipe connection. Oil is admitted into cylinder *19* to raise the milling head through solenoid-operated four-way valve *13*.

In the extreme upper position of the spool of valve *13*, when the solenoid is de-energized, oil passes through a groove of the spool and through check valve *17* to backpressure valve *18* (normal pressure 10 to 12 kg per sq cm)

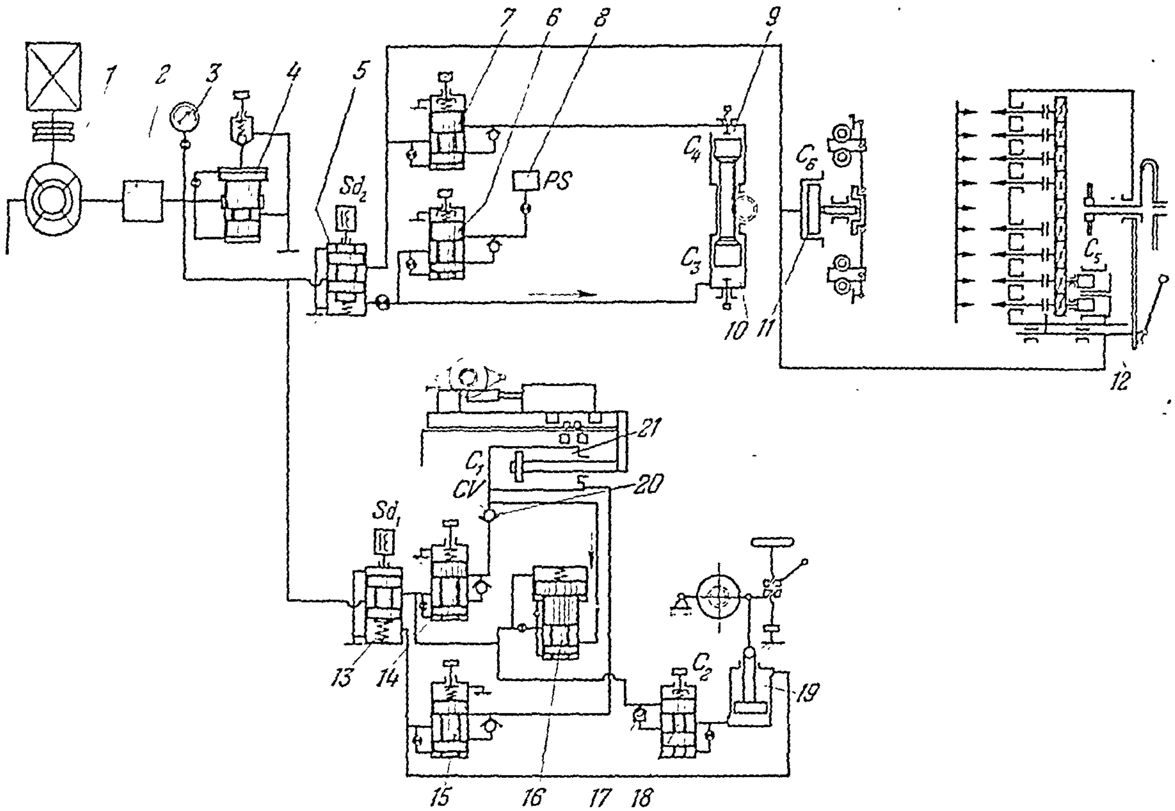


Fig. 307. Hydraulic circuit of the model 6B-1M semiautomatic milling machine

from where it is admitted to the lower (head) end of cylinder *19*. This retracts the cutters from the blanks. In the end position of the milling head, when the oil pressure increases, oil from four-way valve *13* overcomes the force of the spring and shifts the spool of valve *14*. This admits oil through check valve *20* into the left (head) end of cylinder *21* for table traverse. At this the table rapidly returns to its initial position. When the pressure reaches a value at which pressure switch *8* is operated, the solenoid of four-way valve *13* is energized. As a result, the spool of this valve is shifted downward, compressing the spring, and oil is admitted to the upper (rod) end of cylinder *19* so that the milling head is lowered to the preset depth of cut, bearing against a positive stop. When this occurs, the oil pressure increases again, shifting the spool of valve *15* and admitting oil into the right (rod) end of cylinder *21*. This is the working feed motion. From the left end of cylinder *21* oil drains through pressure-compensated flow-control valve *16*. This valve provides for a stable working feed and the possibility of stepless feed regulation.

Thus, the required definite sequence of operations, consisting of cutter approach followed by the working feed, and cutter retraction followed by rapid table withdrawal, is effected by the part of the hydraulic circuit described above.

Oil is also admitted into the quill clamping cylinder and indexing mechanism through solenoid-controlled four-way valve *5*.

When the solenoid is de-energized oil is admitted to quill-advancing cylinders *12* and quill-clamping cylinder *11*. After the quills have been clamped, the pressure in the system increases until the spool of sequence valve *7* with the check valve (normal pressure 10 to 12 kg per sq cm) is shifted upward, thereby admitting oil into cylinder *9* of the indexing mechanism. The piston is shifted to a positive stop, returning the mechanism to its initial position.

When the solenoid of four-way valve *5* is energized, its piston compresses the spring and is shifted downward, admitting oil to cylinder *10* of the indexing mechanism. Oil from cylinders *11* and *12* is then discharged to the tank, thereby unclamping the quills.

The travel of the piston in cylinder *10* actuates the indexing mechanism. Oil drains from cylinder *9* through a check valve back to the tank. The piston is shifted up to a positive stop and consequently the pressure in the system increases until the piston of sequence valve *6* with a check valve (normal pressure 14 to 16 kg per sq cm) is shifted upward, admitting oil into pressure switch *8* (normal pressure 16 to 17 kg per sq cm).

The action of the pressure switch energizes the solenoid of four-way valve *13*, after which the milling head is lowered to the working position and the working feed is imparted to the table.

The hydraulic system is to be filled with clean, carefully filtered mineral oil, grade Industrial 20 or Turbine 22 (Turbine Л).

The hydraulic system can operate properly only when the oil temperature is within the range from 10° to 50°C.

Milling Machine Operation

The controls are arranged on the control panel mounted at the front of the machine. The electric circuit provides for setting-up operation with manual controls and for regular operation with automatic controls.

In operation with manual controls the table is jogged by holding down the FORWARD or RETURN push button. The INDEX push button unclamps the quills and operates the indexing mechanism.

The blanks are milled using the automatic cycle of operation.

The electrical controls incorporate all required interlocking and protecting devices of the electrical equipment. Thus, if the selector switch is turned to the AUTO (automatic cycle) position, the FORWARD, RETURN and INDEX push buttons are interlocked.

The automatic cycle consists of a series of elements whose sequence is ensured by the operation of the corresponding items in the hydraulic system and electrical equipment:

(a) The quills are unclamped and the blanks are indexed after a flute has been milled on the blanks, the milling head has been raised and the table has returned rapidly to its initial position. To accomplish this, a dog fastened on the table operates a limit switch which energizes solenoid Sd_2 (Fig. 307), making the required change-over in the hydraulic system.

(b) This is followed by the advancing and clamping of the quills, lowering of the milling head and return of the indexing mechanism to the initial position. When the pressure switch operates, solenoid Sd_2 is de-energized and solenoid Sd_1 is energized. This changes over the hydraulic system to effect the given operations.

(c) Working feed of the table takes place after solenoid Sd_1 is energized by the pressure switch, beginning when the milling head has been lowered.

(d) The milling head is raised and the table returns rapidly to its initial position when the second dog fastened on the table operates a limit switch. This de-energizes solenoid Sd_1, making the required change-over in the hydraulic system.

The control system makes provision for switching on the electric motor of the hydraulic pump when the machine is switched over to the automatic cycle. In operation with manual controls, this motor is switched on when table travel and the indexing mechanism are engaged. In operation on an automatic cycle, the machine is automatically switched off when the preset number of flutes have been milled (consequently, after the required number of indexing operations). This number is counted off by a pulse-counting relay (*PCR*) set to the required number of flutes (from 3 to 25). This relay can be reset to initial position, if the cycle is interrupted for some reason, by pressing the reset button (*R*).

The control devices are accommodated on two panels housed in a cavity of the base.

Cutting fluid for cooling the cutters is delivered by a pump (type МД-22) powered by a 0.125-kW electric motor running at 2,800 rpm. The pump motor is switched on and off together with the cutter spindle drive motor.

The cutting fluid is delivered to each cutter, and it washes the main part of the chips into the chip collector.

17-4. Semiautomatic Three-Position Milling Machine, Model МИ-10, for Milling Helical Flutes of End Mills

This milling machine (Fig. 308) is intended for milling the helical flutes of end mills 20 to 60 mm in diameter with irregular tooth spacing (according to USSR Std GOST 8237-57). The machine can also be used for milling

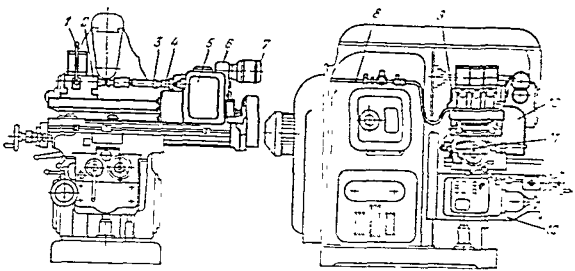


Fig. 308. Semiautomatic three-position milling machine, model МШ-10, for milling helical flutes of end mills

1—air valve lever; *2*—tailstocks; *3*—chuck; *4*—push-button station; *5*—indexing gearbox; *6*—three-spindle headstock; *7*—electric motor; *8*—pneumatic equipment; *9*—attached table; *10*—guide lead change gears; *11*—bar with dogs; *12*—universal horizontal milling machine, model 6H82

the straight or helical flutes of core drills, reamers and other similar tools with either regular or irregular spacing.

This is a specialized machine designed on the basis of the universal horizontal milling machine, model 6H82.

The principal specialized units are the attached tilting table, three-spindle headstock, indexing gearbox and the air-operated tailstocks.

The attached table (Fig. 309) is of cast iron; three T-slots in the top of the table are used to secure the tailstocks at the left and the three-spindle headstock at the right. The end-mill blanks are held between the centres of the headstock and tailstocks.

The indexing gearbox, effecting simultaneous indexing of all the blanks after each pass, is secured to a flange of the headstock.

The tailstocks can be adjusted along the top surface of the table to suit the length of the blank and the helix angle of the flutes.

The attached table is pivoted on the standard table of the machine so that it can be retracted to prevent wear of the relief surfaces on the cutter from rubbing against the work during the return stroke of the table. Pin *33* serves as the pivot and right-hand support of the table. This pin is mounted in bracket *34* which is secured in the T-slots of the standard table.

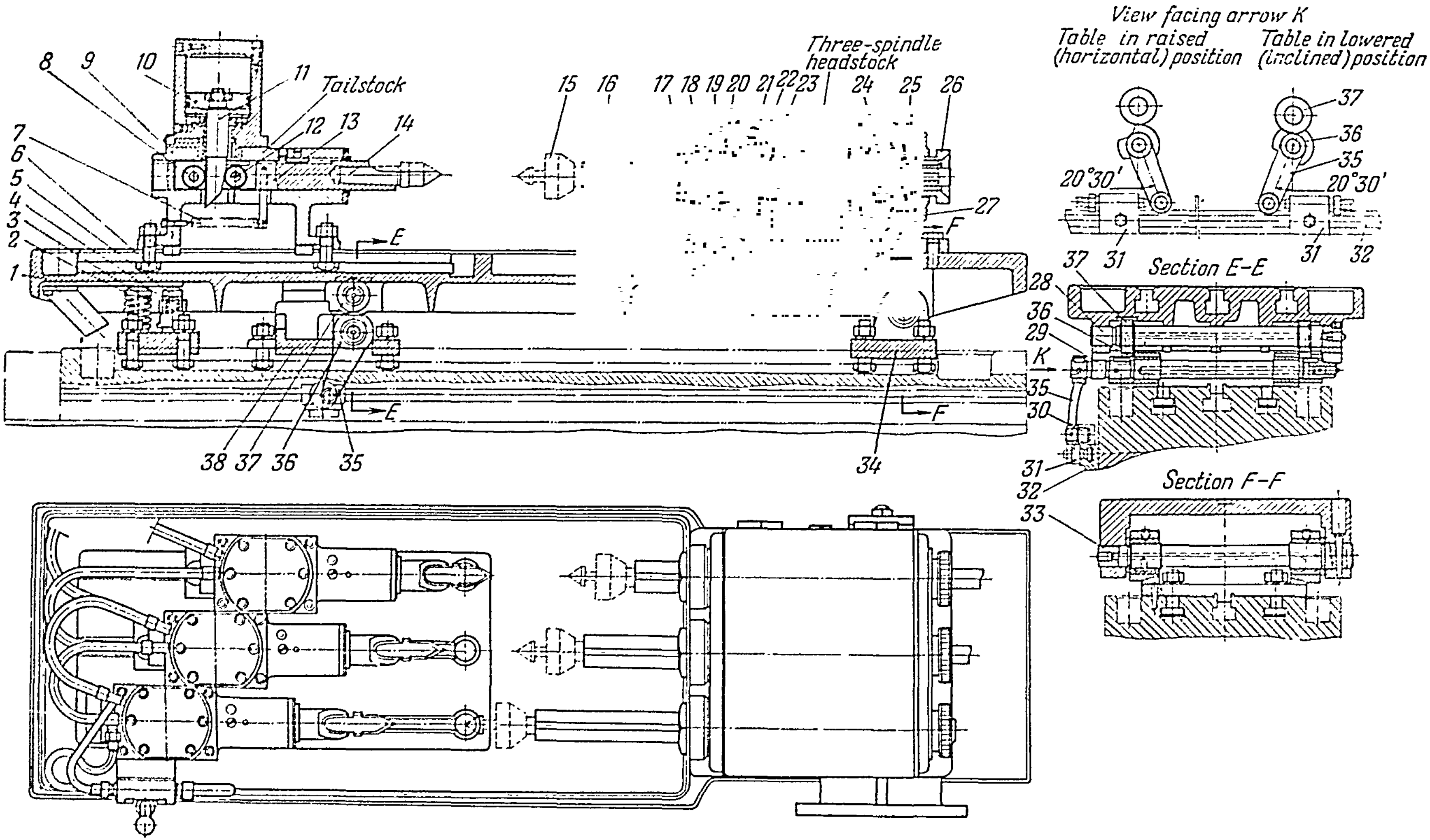


Fig. 309. Attached table with the headstock and tailstocks (model МИ-10)

The mechanism for lowering the table consists of the cam mechanism and bar *32* secured to the column. Adjustable dogs *31* are set up along the slot of the bar to suit the length of the flute being milled on the blank. Rollers *37*, bearing on cams *36*, are freely mounted on shaft *28* which is assembled in the attached table (Section *E-E*). The cams are fastened on shaft *29* which rotates freely in the bearings of bracket *38*. The latter is secured on the standard table.

Lever *35* with press-fitted pin *30* is mounted on the end of shaft *29*. At the end of the return stroke of the table, pin *30* runs up against left-hand dog *31*, thereby turning the cams which raise the table to set in into the horizontal position corresponding to the working stroke.

At the end of the working stroke, lever *35* meets the right-hand dog, turning the cams so that rollers *37* drop into recesses of the cams. This leads to lowering (tilting) of the attached table which is then rapidly returned.

Rests *2* and *5*, supported by springs *3* and *4* in the left-hand part of the attached table, relieve part of the load acting on the lowering mechanism.

The standard table of the machine can be swivelled together with the attached table to an angle that depends upon the helix angle of the flutes being milled.

Three-spindle headstock. Three spindles *19* (Fig. 309) are mounted in antifriction bearings in housing *22*. These spindles are driven through worm gearing, *27* and *24*, from the indexing gearbox. The front support is a tapered-bore roller bearing *21* with clearance adjustment fitted on the tapered journal of the spindle. This arrangement allows fine adjustment of the radial clearance. The application of a bearing of this type also increases the rigidity of the spindle unit. Chuck *15* with a floating centre is inserted in the front end of quill *16* which is mounted in the bore of spindle *19*. Torque is transmitted from spindle *19* to quill *16* through feather *23*.

To mill helical flutes, the standard table is swivelled to an angle equal to the helix angle of the flutes. Therefore, quills *16* must be extended different lengths so as to align the blanks with the gang of cutters. This is accomplished by threaded sleeves *25* screwed on thread provided for this purpose on the quills. When handwheel *26* is rotated the quill is adjusted axially. After extending the quill as required, it is clamped in reference to spindle *19* by collet *18* which is closed by turning nut *17*.

The axial load on the spindle is carried by ball thrust bearing *20*.

The *indexing gearbox* (Fig. 310) is designed for automatically indexing the blanks through a preset angle. It is also a transmission unit for linking rotation of the lead screw in the standard table with rotation of the blanks in milling helical flutes.

The indexing gearbox is mounted on a flange of the headstock (see Fig. [illegible]).

The blanks are indexed by means of index plate *1* (Fig. 310); they are rotated for indexing by electric motor *28* which runs continuously.

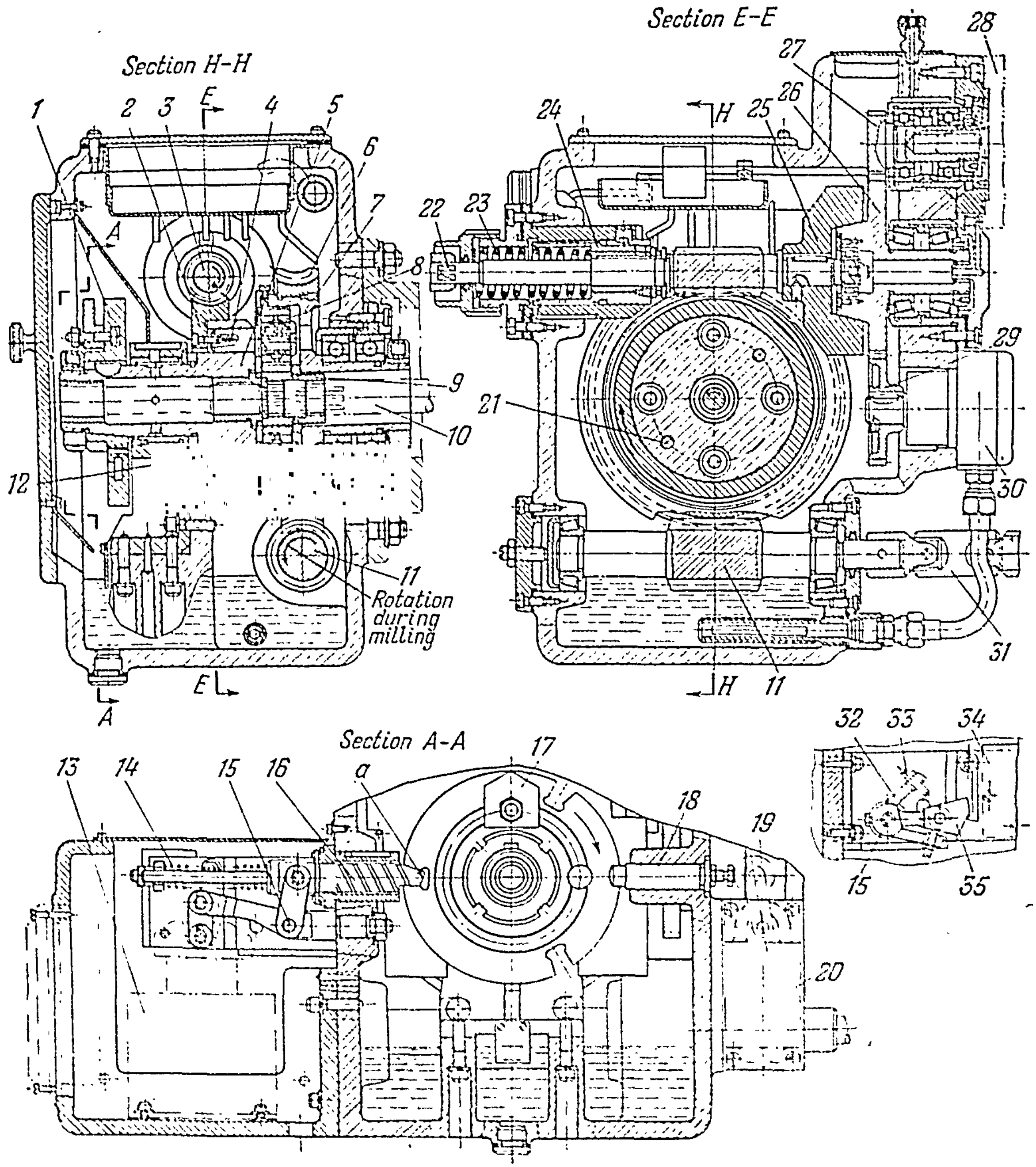


Fig. 310. Indexing gearbox (model MH-10)

Indexing occurs at the moment when the table stops at the end of the return (idle) stroke. A time-delay relay is energized at this point and, after 1 to 1.5 seconds have elapsed, it energizes solenoid *13* which pulls locking member *16* out of the slot of index plate *1*.

Spring *23* shifts sliding sleeve *21* together with worm *3* axially to engage cone clutch *25*. The axial motion of worm *3* starts rotation of worm wheel *2* and, after the conical surfaces of the clutch come into contact, rotation of worm wheel *2* and index plate *1* is powered by motor *28*.

As the index plate begins to rotate, the lower, following edge of the locking slot engages the bevelled end *a* of locking member *16* pushing it back an additional amount. This turns shaft *15* on which forked lever *32* with adjusting screws *33* is mounted. The screw of the upper lever actuates cam *35* and the bevel of this cam operates limit switch *34* which de-energizes solenoid *13*.

The index plate is mounted on the end of thrust bushing *5* which is powered by the 0.27-kW motor, running at 1,400 rpm, through gears *27* and *26*, cone clutch *25* and worm gearing *3* and *2*.

The number of slots and their angular spacing on the index plate must correspond to the number of flutes on the tool being milled and their angular spacing

Therefore, the angular velocity of the index plate must correspond to that of the rotating blanks For this purpose, driving shaft *10* of the three-spindle headstock is powered from worm wheel *2* through planetary gearing. Axles *4* of planet pinions *8* in this mechanism are fixed in the flange of thrust bushing *5*. These axles are fastened to worm wheel *2* by means of screws *12* and dowel pins *21* Sun gear *9* of the planetary gearing is mounted on the six-splined end of driving shaft *10* of the headstock.

The ratio of the planetary gearing $\left(i_{pl} = \frac{4}{1}\right)$ compensates for the ratio of the worm gearing, *27* and *24* $\left(i_{27,24} = \frac{1}{4}\right)$ (Fig. 309), which transmits rotation from the driving shaft to spindle *19* of the headstock, so that the overall transmission ratio is

$$i = i_{pl} i_{27,24} = \frac{4}{1} \times \frac{1}{4} = 1$$

When the blanks have been indexed, locking member *16* (Fig 310) is pushed by spring *14* into the next slot of the index plate; this turns fork lever *32* in the opposite direction so that limit switch *34* transmits a command signal to switch on the feed drive motor. As a result, the lead screw begins rotating and traversing the table. This part of the cycle is the working feed, and the helical flutes are milled on the blanks.

In this case, rotation is transmitted to driving shaft *10* from the lead screw through a number of gears with an overall ratio $i = 1$ (Fig. 311).

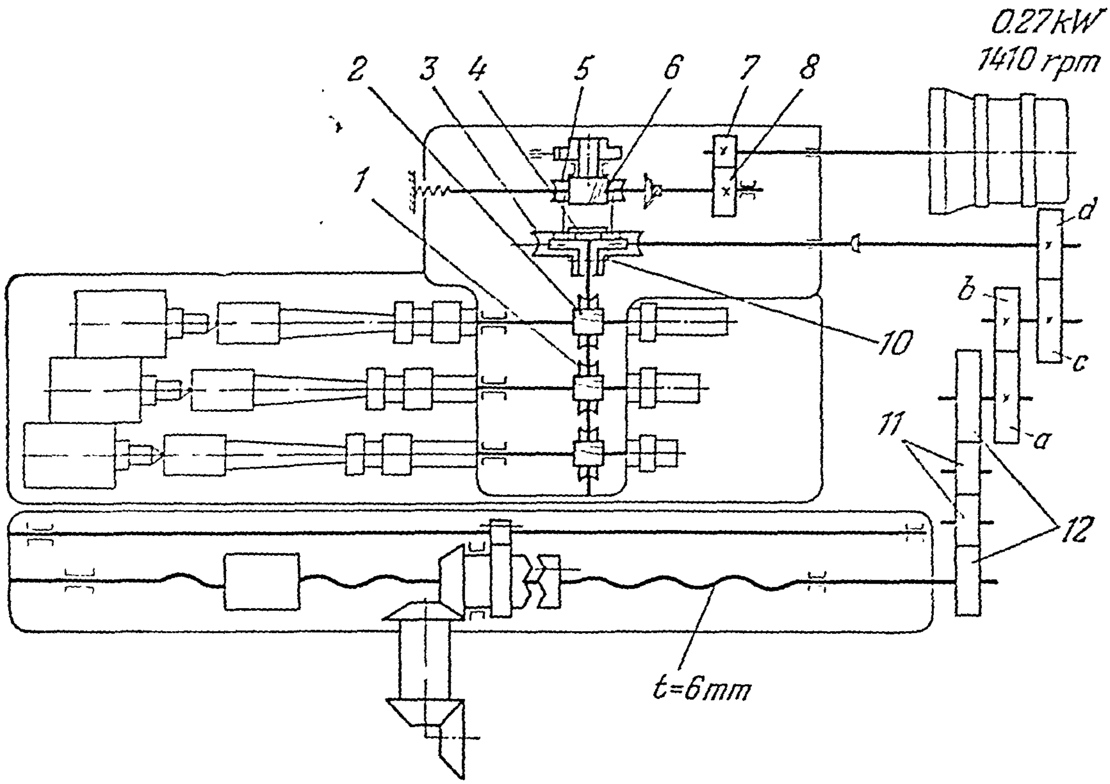


Fig. 311. Gearing diagram of the specialized units in the model МИ-10 milling machine

feed change gears a, b, c and d, jointed coupling *31*, worm *11* and worm wheel *6* of the indexing gearbox (Fig. 310). Since cone friction clutch *25* is disengaged and index plate *1* is locked, planet pinions *8* serve as intermediate gears transmitting rotation from internal gear *7* to sun gear *9*.

Setting up the gear train to obtain the required flute lead (Fig. 311). The gear train can be represented by the equation

$$P = 1 \times \frac{z_1}{z_2} \times \frac{z_4}{z_{3int}} \times \frac{z_{3ext}}{z_{10}} \times \frac{d}{c} \times \frac{b}{a} \times \frac{z_{12}}{z_{11}} \times \frac{z_{11}}{z_{12}} \times t$$

where P = lead of the helical flutes, mm

t = lead of the lead screw, mm.

Substituting the values of the number of teeth from Table 50 and the value of t (6 mm), we obtain

$$\frac{a}{b} \times \frac{c}{d} = \frac{180}{P}$$

TABLE 50

No. in the diagram (Fig. 311)	Name	Number of teeth z
1	Worm wheel (L.H.)	20
2	Worm (L.H.)	5-start
3	Worm wheel (external)	45
	Internal gear	66
4	Gear	22
5	Worm wheel	60
6	Worm	1-start
7	Gear	30
8	Gear	90
9	Change gears	35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90 and 100
10	Worm	2-start
11	Gear	24
12	Gear	38

When all the flutes have been milled and, consequently, after index plate *1* makes one full revolution (Fig. 310), cam *17* actuates pin *18* which operates roller *19* of limit switch *20*. The latter stops the machine.

The machine is set up to index the required number of flutes by merely installing an index plate with the required number of slots. In installing the plate it is necessary to align the locking member with the slot in the plate and the keyway in the plate with the key on the shaft. To accomplish this, the shaft is turned by putting a crank handle on square shank *22* at the end of the worm shaft and turning as required.

Cam *17* is set up on each index plate so that after one revolution of the work (after milling all the flutes) and after operating roller *19* of limit switch *20*, the cam will turn through an angle of 15° to 20° before the machine stops.

The rubbing parts of the indexing gearbox are lubricated by built-in pump *30* which is driven through gears *26* and *29*

The *tailstocks* (Fig. 309) are operated by compressed air at a pressure of $p = 4.5$ to 5 kg per sq cm. The blanks are mounted between the centres and the milled work is removed by hand

In mounting the blanks, the floating centres of the headstock are pushed back one at a time. Then the blanks are clamped simultaneously by turning lever *1* of the automatic air valve (Fig. 308). As piston *10* (Fig. 309) travels downward, the wedge-shaped end of rod *11* bears against roller *12*, fitted into a slot of quill *13*, pushing forward the quill together with centre *14*, the blank and the floating centre. Spring *7* returns the quill to its rear (retracted) position. The flutes are milled by the climb-cut method so that the feed pressure is carried by roller *8* mounted in housing *9* of the tailstock.

Depending upon the helix angle of the flutes being milled, and the overhang of the headstock quills, the tailstocks are set up and clamped by T-bolts *6* in the T-slots of attached table *1*.

The pneumatic equipment consists of the air valve, reducing valve with pressure gauge, and check valve. The latter prevents the blanks clamped between the centres from being thrown out if there is a pressure failure in the air supply line.

The following data refer to this machine:

Brief Specifications of Semiautomatic Milling Machine, Model MH-10

Distance between the headstock and tailstock centres, mm	0 to 385
Distance from the cutter spindle axis to the table, mm .	30 to 220
Height of centres, mm	100
Diameter of end mill whose flutes can be milled, mm .	20 to 60
Length of flute milled, mm	50 to 300
Lead of helical flutes milled, mm	90 to 270
Type of flutes milled	R.H. helical
Maximum helix angle of flute milled, deg	35

The cycle of operation of the machine consists of the following elements: rapid approach of the blanks (about 20 mm), working feed, rapid return of the table to the initial position, and blank indexing through the required angle.

Then the cycle is repeated until all the flutes have been milled, after which the machine stops automatically.

After removing the milled workpieces and loading new blanks, the machine is started again by pressing the START push button.

The electric circuit incorporates the following interlocking features controlling the position of the locking member and operation of the feed drive motor: the locking member cannot be retracted from the slot of the index plate while the feed motor is in operation, and the motor cannot be switched on if the locking member is extended.

CHAPTER 18

THREAD-CUTTING MACHINES

18-1. Precision Threading Lathes

General

Precision thread-cutting machines are employed in the tool and instrument industries to cut precise threads in the manufacture of micrometer screws, *thread gauges, long (staybolt) taps, etc.*

As a rule, the pitch of the thread is set up in these machines by means of change gears, in conjunction with a lead screw and nut. The gears of the feed gear train and the lead screw must be finished to a high degree of precision. The design of the headstock spindle must be one that ensures smooth running. This requirement is often met by using a belt in the main drive from the electric motor to the spindle. In most cases, the design provides for relieving the spindle of the belt tension Ball and roller bearings of the highest grades of accuracy are used. Sleeve bearings are of the adjustable tapered bushing design. Accuracy standards have been established for precision thread-cutting machines by USSR Std GOST 1969-43.

Thread-cutting machines may or may not have a correction bar, or pitch compensator. The accuracy of thread cut by machines having a correction bar is characterized by the following data: the accumulated pitch error of the thread should be within 0.003 mm over a length of 50 mm; within *0.004 mm over a length of 150 mm, and* within 0.005 mm over a length of 300 mm These errors are only one-fourth to one-third of the errors obtained in machines that are not equipped with a correction bar.

The high pitch accuracy attained with the application of a correction bar is due to supplementary *rotation of the lead screw nut, providing* additional movement of the carriage to correct the pitch. The required supplementary rotation of the nut can be produced by means of a straight correction bar set at a certain definite angle The use of such an arrangement leads to:

(1) compensation for the accumulated pitch error of the screw;

(2) an increase or decrease in the thread pitch by a definite amount, i.e., in a definite proportion, to compensate for deformation in subsequent heat treatment;

(3) compensation for the effect of the difference in the coefficients of linear expansion of the work material and the lead screw material on the *thread pitch;*

(4) compensation for the effect of the deviation of temperature of the room in which the thread-cutting machine is installed from the normal temperature (20°C) on the accuracy of the pitch of the thread being cut.

Moreover, if the errors of the separate pitches of the lead screw thread are measured, and a corresponding curvilinear profile is constructed on the correction bar, it will prove possible to impart rotation to the nut that will compensate for the pitch errors of the lead screw.

Determining the Angular Setting of the Correction Bar

Compensation is made for changes in thread pitch resulting from deformation produced by subsequent heat treatment by setting the correction bar to the angle β which is calculated in the following way.

We shall assume that, as a result of heat treatment, the length L of the thread is changed by the amount ΔL. If the correction bar is set to the angle β (Fig. 312) then, during the travel of the carriage over a length L along the bed, the roller of the correction lever will be displaced crosswise by the value $h = L \tan \beta$ and the nut will turn a fraction of a revolution, equal approximately to $\frac{h}{2\pi R}$, where R is the effective length of the correction lever. Additional rotation of the nut leads to additional travel of the carriage:

$$\Delta L = \frac{h}{2\pi R} t_{ls} = \frac{L \tan \beta}{2\pi R} t_{ls}$$

where t_{ls} = pitch (or lead) of the lead screw.

It follows that

$$\tan \beta = \frac{2\pi R \Delta L}{L t_{ls}}$$

Since $\frac{2\pi R}{t_{ls}} = p$ is a constant value for a definite thread-cutting machine

$$\tan \beta = p \frac{\Delta L}{L} \tag{31}$$

It is evident that

$$\frac{\Delta L}{L} = \frac{\Delta t_{fw}}{t_c}$$

where t_{fw} = thread pitch of the finished work

t_c = thread pitch as cut;

therefore, the preceding formula can be written as

$$\tan \beta = p \frac{\Delta t_{fw}}{t_c} \tag{32}$$

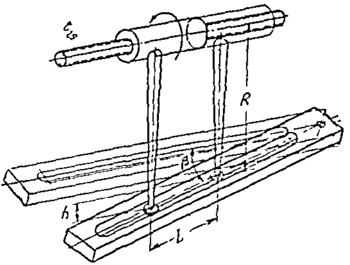


Fig. 312. Principle of the correction bar

An almost identical formula is used to calculate the bar setting to compensate for pitch errors Δt_{ls} of the lead screw. Thus

$$\tan \beta = p \frac{\Delta t_{ls}}{t_{ls}} \tag{33}$$

Deviations in the pitch of thread being cut due to variations of the shop temperature from the normal value, as well as pitch errors due to different coefficients of linear expansion of the workpiece and lead screw materials are also compensated for by setting the correction bar to an angle β_1. This angle is computed on the basis of the following considerations.

The error Δt_{fw} in the pitch of the part (t_c) is

$$\Delta t_{fw} = t_c (\alpha_1 - \alpha_2)(T_{sh} - T_n)$$

where α_1 = coefficient of linear expansion of the workpiece material
α_2 = coefficient of linear expansion of the lead screw material
T_{sh} = shop temperature at the time the thread is being cut
T_n = normal shop temperature at which the machine was adjusted.

Substituting this value of Δt_{fw} into equation (32) we obtain

$$\tan \beta_1 = p (\alpha_1 - \alpha_2)(T_{sh} - T_n) \tag{34}$$

The profile of the correction bar is made curvilinear to compensate for pitch errors of the lead screw. The size of each valley or ridge in the profile

depends upon the magnitude of the error in the corresponding pitch of the lead screw. If the pitch error is Δt_{ls}, the amount the nut must be turned (fraction of a revolution) to compensate for this error is equal to

$$\frac{h}{2\pi R}=\frac{\Delta t_{ls}}{t_{ls}}$$

where h is the amount the roller must be raised or lowered, i.e., the height of the ridge or depth of the valley on the profile of the correction bar.

Therefore

$$h=\frac{2\pi R}{t_{ls}}\,\Delta t_{ls}=p\Delta t_{ls} \tag{35}$$

For example, if the machine has a ratio of $p = 200$ and the error in a certain pitch of the lead screw is $\Delta t_{ls} = 0.005$ mm, value h for the given pitch is 1 mm. After measuring the error of each pitch along the lead screw and making the necessary calculations, the profile of the correction bar (curve of ridges and valleys) is plotted.

18-2. Semiautomatic Precision Threading Lathe, Model 103

This lathe is intended for cutting internal and external high-accuracy threads, and finds application in the tool industry and in plants producing precise instruments.

The design of the lathe enables threads to be cut up to a shoulder, as well as taper and multiple-start threads. The lathe can cut metric thread with a pitch from 0.25 to 5 mm, and inch thread in a range from 5 to 24 tpi. The diameter of the thread ranges from 5 to 30 mm. The height of centres is 100 mm; the maximum distance between centres is 300 mm.

Circular form tools are used to cut external thread; special single-point threading tools or chasers are used for internal thread.

The electric circuit of this semiautomatic lathe provides for the following cycle: tool approach to the work; working travel; tool recoil from the work; and rapid return traverse.

When the thread has been cut to the preset depth, the tool cleans up the thread in the number of passes to which a counting relay has been set up, after which the lathe stops automatically. A signal lamp indicates that the preset depth of the thread has been reached.

The lathe consists of the bed, base, headstock, reducing gear, carriage, lead screw and feed change gears, cam mechanism, tool recoil mechanism, tailstock, toolholder, correction bar, electrical equipment and coolant system.

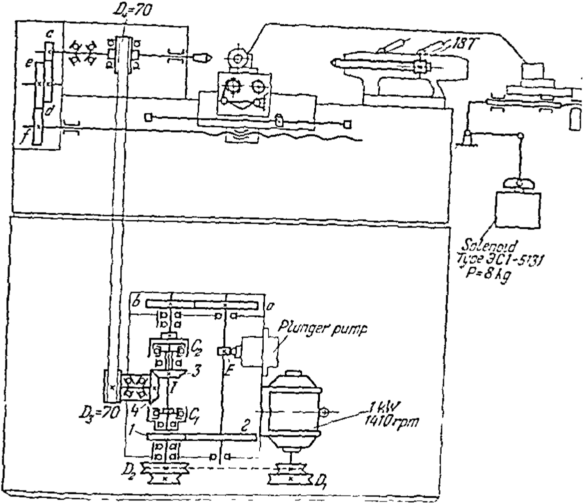


Fig. 313. Gearing diagram of the model 103 semiautomatic precision threading lathe

The semiautomatic lathe has attachments for cutting multiple-start threads, for cutting thread up to a shoulder and for grinding centres. The faceplate is a standard accessory.

The gearing diagram of the lathe is shown in Fig. 313.

The spindle is powered by a 1-kW electric motor running at 1,410 rpm through a V-belt drive, reducing gear with change gears, and a flat-belt drive. The spindle is relieved of the belt tension. A bronze bushing with an external taper is press-fitted on the front cylindrical journal of the spindle.

This bushing runs together with the spindle in a steel liner of the front bearing. The rear end of the spindle is mounted in two precision angular-contact ball bearings operating with a constant spring-applied load.

Either a faceplate or a collet chuck can be installed and clamped in the tapered hole of the spindle. During working traverse, rotation is transmitted to the spindle through spur gears *1* and *2* (Fig. 313), change gears *a* and *b*, and bevel gears *3* and *4* of the reducing gear. During the rapid return of the carriage, rotation is transmitted directly through bevel gears *3* and *4*.

Spindle rotation is reversed by reversing the drive motor.

The ends of shaft *I*, on which bevel gear *3* is mounted, are linked to the inner members of overrunning clutches C_1 and C_2. During the working traverse of the carriage, clutch C_1 slips (being automatically disengaged, since it transmits torque only in one direction) and rotation is transmitted to the spindle through the change gears and clutch C_2. When the motor is reversed to provide the rapid return traverse, the rollers of clutch C_1 jam and the clutch begins to transmit rotation to the spindle directly through bevel gears *3* and *4*. During these parts of the cycle, overrunning clutch C_2 will slip since it is engaged only when shaft *I* rotates in the other direction.

The lathe is set up to cut left-hand thread by interchanging the directions of the working and return traverse. This is done by installing an idler gear in the feed change gear quadrant $\frac{c}{d} \times \frac{e}{f}$, and switching over certain elements of the solenoid circuit that provides for tool recoil.

The electric motor is mounted on the cover of the reducing gear, on a pivoted base enabling the tension of the V-belt to be readily adjusted. To enable the tension of the flat belt to be adjusted, the reducing gear housing is pivoted on a base mounted inside the lathe base.

Eccentric cam *E* on the intermediate shaft of the reducing gear drives the plunger pump of the coolant system.

If the V-belt is put on the smaller step of the motor pulley, spindle speeds will range from 39 to 355 rpm, depending upon the installed change gears *a* and *b*, and will be 400 rpm during the rapid return traverse. The spindle speed range for the larger step of the pulley is from 70 to 530 rpm, with a return traverse speed of 710 rpm.

The carriage (Fig. 314) consists of saddle *9*, cross slide *2* and compound slide *4*. The saddle is traversed along the dovetail bed ways by the lead screw. The latter is driven from the spindle through the feed change gears (Fig. 313) serving to set up the required thread pitch.

Two pairs of limit switches *16* and *19* (Fig. 314) are mounted on the front pad of the saddle. Their purpose is to reverse carriage travel and spindle rotation at the proper points of the cycle. Two of these limit switches are provided for emergencies; they stop the lathe in cases when the main limit switches fail to operate. The dogs that actuate these switches have two

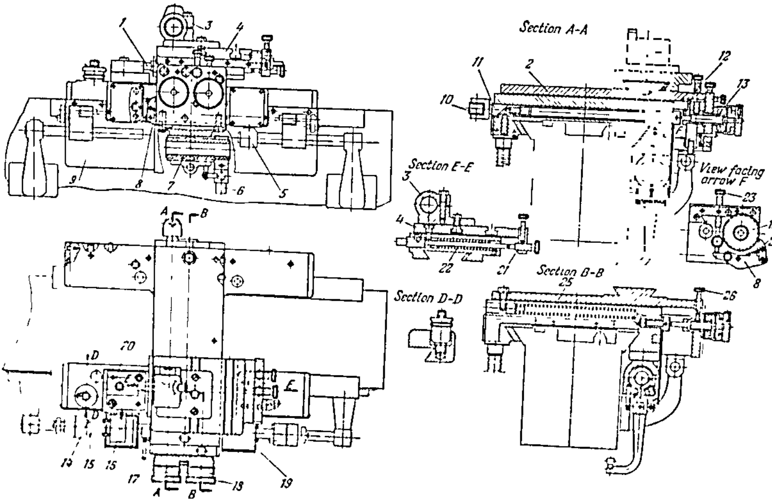


Fig. 314. Carriage of the model 101 semiautomatic precision threading lathe

spring-loaded pins *14* and *15* each. The pins are of different height: the higher pin for operating the main limit switch, and the lower for the emergency switch.

Cross slide *2* travels along the ways on the saddle *9*. Spring *25*, located inside the saddle, constantly forces the cross slide together with the clamped tool toward the work being threaded.

The cross slide has two micrometric screw stops *17* and *18*. Right-hand stop *18* serves to set the tool to the depth of cut; the thimble of this stop is graduated in 0.005-mm divisions. The stop is locked in the set-up position by screw *26*. Left-hand stop *17* serves for cross feed of the cutting tool. Ratchet wheel *12* with 200 teeth is secured on the screw *13* of stop *17*. During the return traverse of the carriage, lever *8* of pawl *24* runs up against adjustable dog *5* and turns ratchet wheel *12*, and consequently screw *13* of stop *17*. This enables spring *25* to feed the cross slide forward a certain amount. Ratchet wheel rotation corresponds to a cross feed of 0.0025 mm per tooth, the maximum feed (corresponding to rotation through 20 teeth) is 0.05 mm per pass of the carriage. The feed is set up by adjusting screw *23* which changes the throw of the pawl.

The cross slide is withdrawn at the end of working travel as follows. Roller *10*, at the end of push-rod *11*, is in contact with a bar linked to a solenoid. At the end of working travel, the solenoid shifts the bar, and push-rod *11*, bearing against screw *13* of stop *17*, compresses spring *25* and withdraws the cross slide, which remains in this position during the whole return travel.

The compound, or tool, slide *4* can be traversed longitudinally along the ways on cross slide *2*. This motion is used in matching previously cut thread, for feeding in the tool at an angle and for cutting thread up to a shoulder.

In setting up, the tool slide is adjusted by turning screw *21* which retracts the tool slide, compressing spring *22*.

The tool is fed in at an angle (cutting is done by one edge) by installing cam *20*, bevelled to suit the thread angle, on the saddle. Infeed proceeds with power cross feed. The tip of follower *1* slides along the bevel of the cam and permits the tool slide to travel in the longitudinal direction as well due to the action of spring *22*. The second stop *18* must be withdrawn for this purpose. This combination of cross and longitudinal feeds, controlled by cam *20*, feeds the tool into the thread at the required angle.

At the moment when the tool reaches the shoulder on the work, in cutting thread up to a shoulder, the tool stops travelling but the carriage continues for 1 to 5 mm before it is reversed. This overtravel merely compresses spring *22*.

Tool head *3* for clamping the toolholder is secured on the tool slide. A scale with 1° divisions is engraved on the tool head to enable the toolholder to be

set up accurately in the bore of the head. The axis of the bore in the tool head is 7 mm above the line of centres of the lathe.

A correction bar (see Sec. 18-1) compensates for pitch errors of the lead screw within the production tolerances and for variations in the temperature. The correction bar is of swivelling design to correct a progressive pitch error or to change the pitch of the thread being cut so as to compensate beforehand for deformation due to subsequent heat treatment. The bar is swivelled by two screws, one having a dial. One dial division corresponds to a change in pitch of the thread being cut equal to 0.1 micron (0.0001 mm) per 100 mm of length. The surface of the bar along which the end of lever *6* slides has a curved profile. This lever is linked rigidly to nut *7*. Upon longitudinal travel of saddle *9*, lever *6* turns nut *7* through definite angles in one or the other direction, thereby increasing or reducing the corresponding pitch of the thread being cut.

Taper threads can also be cut in this lathe. If the taper is small, the thread can be cut by offsetting the tailstock centre. In other cases a special taper attachment is employed. It is installed in place of the bar for automatic withdrawal of the carriage. During saddle travel, roller *10* runs continuously along the active surface of the special taper bar.

CHAPTER 19

THREAD-GRINDING-MACHINES

19-1. General Data

Thread-grinding machines find extensive application in tool production to manufacture threads of the higher grades of accuracy. They are employed to grind the threads of taps, thread gauges, cylindrical thread-rolling dies, thread-milling cutters, etc.

Three thread-grinding methods (Fig. 315) are in common use: grinding with a single-rib wheel, with a cylindrical multiribbed wheel and with a tapered multiribbed wheel.

The *first method* (Fig. 315*a*)—grinding with a single-rib wheel—is used for producing thread of especially high accuracy (1st grade accuracy according to the USSR Std). The pitch error of such thread is within 0.0025 mm over a length of 25 mm and within 0.005 mm over a length of 200 mm.

Thread is ground with longitudinal traverse of the table with the work in respect to the wheel.

The basic displacements are

$$1 \text{ revolution of the work} \rightarrow p$$

where p is the pitch of the thread being ground.

Grinding may be performed:

(a) in one pass, in one direction of traverse, with retraction of the wheel at the end of the pass and rapid return traverse;

(b) in one pass, but in both directions, the first workpiece being ground from the headstock centre, the second, from the tailstock;

(c) in several passes on each workpiece with traverse in both directions.

The *second method* (Fig. 315*b*)—grinding with a cylindrical multiribbed wheel—is applied in cases when a high class of surface finish is required on thread whose accuracy may be somewhat lower than that of threads ground by the first method. This method can be efficiently employed for grinding short threads, the face width of the wheel being slightly larger than the length of the thread being ground. Grinding is performed with wheel infeed (plunge-cut feed) to the full depth of the thread profile while the work rotates slowly.

longitudinally by: a permanent lead screw and change gears, interchangeable lead screws, interchangeable cams (without a lead screw), and special bars (without a lead screw).

(2) With respect to the method used to set the wheel (or work) to the helix angle of the thread (Fig. 316).

To obtain an accurate thread profile in grinding with a single-rib wheel the plane of rotation of the wheel must coincide with the thread helix. This is accomplished by inclining the table with the work (Fig. 316*a*), or by inclining the whole wheelhead (Fig. 316*b*), or only the wheel spindle housing.

(3) With respect to the motions employed in relieving (Fig. 317).

In grinding relieved (backed-off) profiles in a thread grinder, either the work or the wheel has an additional crosswise motion during the grinding operation. In different designs this motion is effected by: rocking of the table with the work about an axis parallel to the work axis (Fig. 317*a*), crosswise reciprocating motion of the wheelhead (Fig. 317*b*), rocking of the wheelhead about an axis parallel to the work axis (Fig. 317*c*), rotation of an eccentric sleeve in the wheelhead (Fig. 317*d*), or lateral oscillation of the tailstock centre (Fig. 317*e*).

Thread grinders are usually equipped with a pitch corrector, or compensator, if the longitudinal travel of the table with the work is effected by means of a lead screw and change gears. The pitch corrector is set up to compensate for the influence of the temperature on the pitch of the thread being ground. The accumulated pitch error of the lead screw can also be compensated for by the corrector.

In most models, correction devices are designed as a swivelling bar (see Sec. 18-1) which affects supplementary rotation of the lead screw nut upon longitudinal travel of the table (Soviet models 5Б82, 5822, etc.).

In order to grind threads that have been previously rough cut in another machine, means must be provided for shifting the work axially in relation to the wheel so as to register the preformed thread with the wheel ("thread matching"). This can be done by adjusting the work axially:

(1) together with the table: with a stationary lead screw by adjusting the lead screw nut (model 5822), and by providing a second, lower table (model MB-14);

(2) together with the table by axial adjustment of the lead screw (model 5Б82);

(3) by adjusting the spindle with the work while the table is stationary, as in the models produced by the Ex-cell-O Corporation (USA) and the Reishauer Co. (Switzerland).

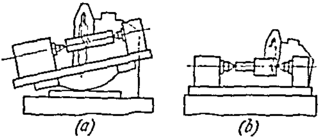


Fig. 316. Setting up to the helix angle of the thread

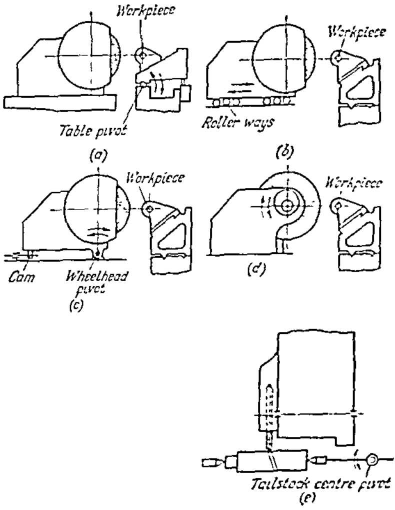


Fig. 317. Motions used in relief grinding

longitudinally by: a permanent lead screw and change gears, interchangeable lead screws, interchangeable cams (without a lead screw), and special bars (without a lead screw).

(2) With respect to the method used to set the wheel (or work) to the helix angle of the thread (Fig. 316).

To obtain an accurate thread profile in grinding with a single-rib wheel the plane of rotation of the wheel must coincide with the thread helix. This is accomplished by inclining the table with the work (Fig. 316*a*), or by inclining the whole wheelhead (Fig. 316*b*), or only the wheel spindle housing.

(3) With respect to the motions employed in relieving (Fig. 317).

In grinding relieved (backed-off) profiles in a thread grinder, either the work or the wheel has an additional crosswise motion during the grinding operation. In different designs this motion is effected by: rocking of the table with the work about an axis parallel to the work axis (Fig. 317*a*), crosswise reciprocating motion of the wheelhead (Fig. 317*b*), rocking of the wheelhead about an axis parallel to the work axis (Fig. 317*c*), rotation of an eccentric sleeve in the wheelhead (Fig. 317*d*), or lateral oscillation of the tailstock centre (Fig. 317*e*).

Thread grinders are usually equipped with a pitch corrector, or compensator, if the longitudinal travel of the table with the work is effected by means of a lead screw and change gears. The pitch corrector is set up to compensate for the influence of the temperature on the pitch of the thread being ground. The accumulated pitch error of the lead screw can also be compensated for by the corrector.

In most models, correction devices are designed as a swivelling bar (see Sec. 18-1) which affects supplementary rotation of the lead screw nut upon longitudinal travel of the table (Soviet models 5Б82, 5822, etc.).

In order to grind threads that have been previously rough cut in another machine, means must be provided for shifting the work axially in relation to the wheel so as to register the preformed thread with the wheel ("thread matching"). This can be done by adjusting the work axially:

(1) together with the table: with a stationary lead screw by adjusting the lead screw nut (model 5822), and by providing a second, lower table (model MB-14);

(2) together with the table by axial adjustment of the lead screw (model 5Б82);

(3) by adjusting the spindle with the work while the table is stationary, as in the models produced by the Ex-cell-O Corporation (USA) and the Reishauer Co. (Switzerland).

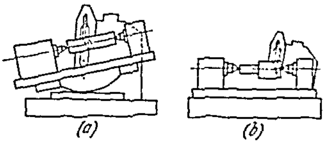


Fig. 316. Setting up to the helix angle of the thread

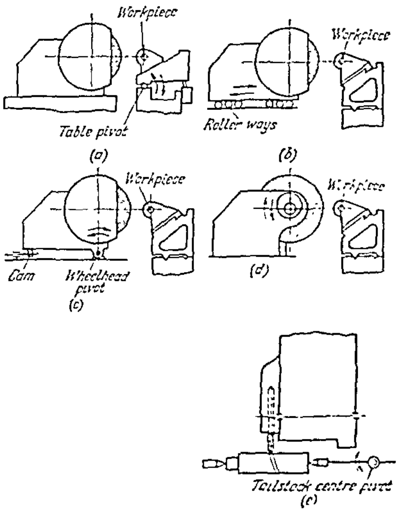


Fig. 317 Motions used in relief grinding

19-2. Universal Thread-Grinding Machine, Model 5582

Purpose. This machine (Fig. 318) is used in various branches of the engineering industries for grinding external and internal, straight and taper, single- and multiple-start threads of the 1st and 2nd grades of accuracy (USSR Std).

In the tool industry, this machine can grind the threads of high-accuracy thread tools, such as thread gauges, taps, thread-milling cutters, cylindrical thread-rolling dies, threading dies, etc. Tool lands may be relieved if necessary in grinding.

The grinder operates with a single-rib wheel on a semiautomatic cycle. Automatic compensation for wheel wear in dressing is available.

Fine-pitch threads can be ground from the solid without preforming.

An interesting feature of the drive is that it is separated from the travelling table, thereby avoiding the detrimental effect of vibration on the accuracy of the thread being ground.

Work spindle rotation and table traverse are powered by a rotary hydraulic motor running at infinitely variable speeds in a range from 193 to 1,290 rpm. The hydraulic system is also used to reverse the table at the end of each stroke, for independent speed adjustment in each direction, and for rapid table traverse in either direction.

The machine has a correction bar. Thread can be ground with a single-rib wheel by any of the three methods described in Sec. 19-1.

The wheel is set to the helix angle of the thread being ground by inclining the wheel spindle housing (Fig. 316*b*).

This grinder is equipped with an automatic wheel dresser and with automatic infeed to compensate for wheel wear.

Special attachments, furnished on special order, are available for grinding with a multiribbed wheel.

Construction and gear train of the spindle drive and table traverse units. The workhead is secured on the table (see Fig. 318). The work spindle is powered by a rotary hydraulic motor through a three-step V-belt drive (Fig. 319) with the ratios $i_1 = \frac{1}{3}$, $i_2 = 1$ and $i_3 = 3$. Rotation is transmitted further through worm gearing $\frac{2}{50}$ and spur gears $\frac{38}{95}$. Upon longitudinal travel of the table, gear *38T* slides along a six-spline shaft.

The application of a hydraulic motor with infinitely variable speeds and the three-step belt drive enables the spindle speed to be changed in a stepless range from 1 to 60 rpm.

The spindle speed is indicated by tachometer (work speed indicator) *3* which is built into the front part of the drive gearbox.

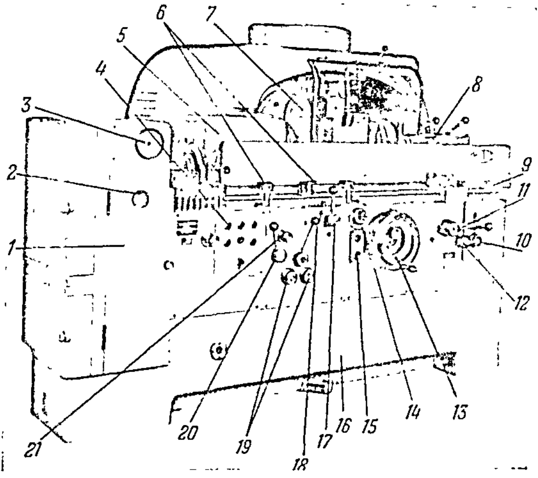


Fig. 318. Universal thread-grinding machine, model 5B82

screws

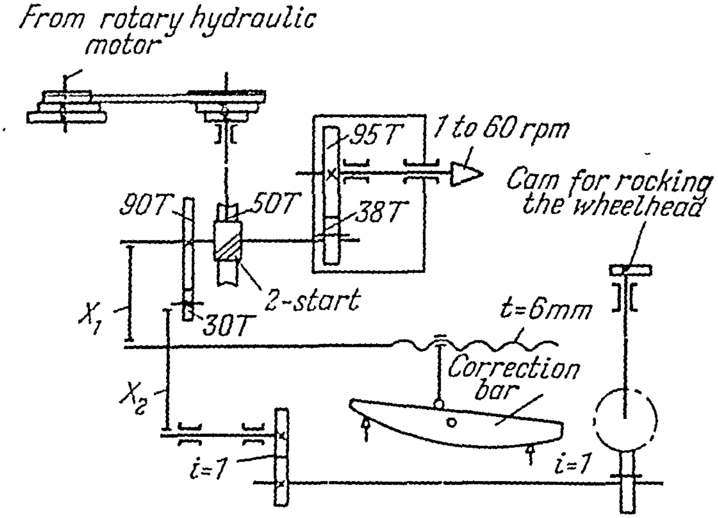


Fig. 319. Gearing diagram of the model 5Б82 thread grinder

The *construction of the workhead* of the model 5Б82 grinder is illustrated in Fig. 320. Spindle *15* of the head runs in sleeve bearings *8* and *14*. The spindle has two cylindrical journals which are ground and lapped to a high degree of accuracy, the out-of-roundness being within 0.001 mm.

The bimetallic bearings *8* and *14* each has three bearing contact strips *a*, *b* and *c*. The upper strip *c* is separated by special slits from the body of the bearing and can be forced inward by regulating screw *17* and clamped by screw *16* to reduce bearing clearance to the minimum feasible value.

Axial clearances are taken up by having shoulder *f* of the spindle bear tightly against end face *g* of bearing *14*, being held in constant contact by the action of springs *12* transmitted through ball bearing *11* and shaped washer *10*. Oil from housing *13* is carried by washer *10* onto troughs *9*, from where it runs down into bearings *8* and *14*.

In grinding a thread in both directions, i.e., during table advance and reversal, it is necessary to reverse spindle rotation as well. When this is being done, the backlash in the gear train between the work spindle and table, as well as that in the thread of the lead screw and its nut, will result in a certain lag in table travel in reference to spindle rotation. This, in turn, will lead to errors in the pitch of the thread being ground. This undesirable effect of inevitable clearances is eliminated by the *backlash compensator*, a device mounted on the end of the work spindle (Fig. 320). This arrangement operates by stopping the work spindle for the period of time required to take up the clearances in the mechanism transmitting motion to the table.

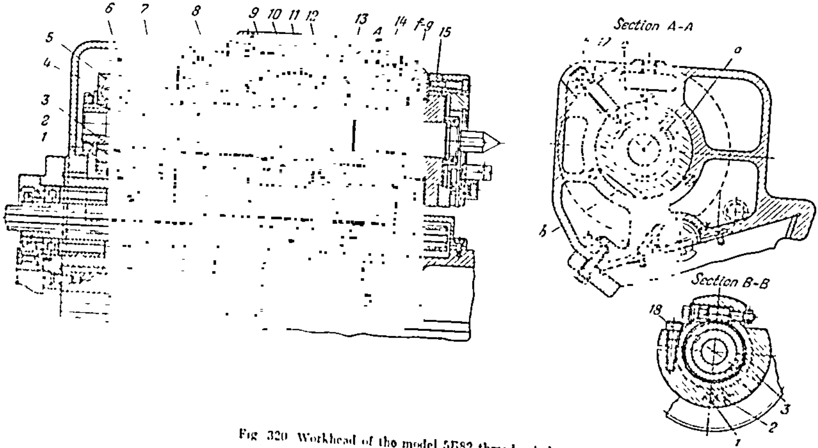


Fig 320 Workhead of the model 5B82 thread grinder

Driven gear *7* with press-fitted pin *2* is mounted freely on work spindle *15* (Fig. 320). Driving member *3* is secured in a slot of bushing *6* which is fixed on the end of the spindle. Teeth cut on the external surface of bushing *6* are in mesh with worm *4*, mounted in yoke *5*. The yoke can be turned on bushing *6* after loosening binding screw *18*.

Driving member *1* is press-fitted in yoke *5*. If this mechanism is set up with a certain clearance between pin *2* and driving members *1* and *3*, at the beginning of reversal, gear *7* will rotate for a certain period without rotating the work spindle. This will continue until pin *2* runs up against one of the driving members, *1* or *3*.

The amount of idle rotation of gear *7* and the consequent dwell of the work spindle are adjusted to suit the backlash in the gear train by turning worm *4*.

The pitch compensator enables the pitch of the thread being ground to be lengthened or shortened by 0.25 per cent, and corrections to be introduced to take the effect of the ambient temperature into consideration.

Correction bar *1* (Fig. 321) is arranged in a plane parallel to the axis of lead screw *3* and can be set to the required angle to this axis by swivelling about pin *2*. In this model, nut *6* has an additional thread cut on its outer surface and is screwed into housing *5* which is fastened to the work table. Flange *4* with lug *a* (see the view facing arrow *B*) is mounted on nut *6* and is held in contact with bar *1* through ball *9* by springs *7*.

If the correction bar is set at an angle, then nut *6* will be turned through a certain angle upon table travel, imparting additional motion to the table and thereby increasing or reducing the main travel imparted to the table by the lead screw mechanism alone.

The grinding wheel is made to accurately engage a preformed thread by longitudinal adjustment of the work table, without the corresponding rotation of the work. This adjustment is incorporated in the design of the bearings of lead screw *3* (Fig. 321).

Sleeve *17*, having a coarse square thread on its outer surface, is fitted in housing *18* which is secured to the base of the grinder. Pin *11* enters one of the thread spaces so that sleeve *17* can be adjusted axially only upon being rotated by means of worm *15* and worm wheel *14* when square shank *14* (Fig. 318) is turned. This square shank is brought out on the front wall of the base. Lead screw *3* (Fig. 321) is secured in sleeve *17* by means of a flange and bronze thrust washers *12* and *13*. Thus, sleeve *17* is screwed into or out of housing *18* when it is rotated. This effects axial adjustment of the lead screw, its nut and, consequently, the work table of the grinder.

Construction and gear train of the wheelhead and grinding wheel. The wheel spindle (Fig. 322) is powered through belt drive *5* from d-c electric motor *4* which is supplied from a 4.8-kW generator. The latter is driven by an a-c electric motor.

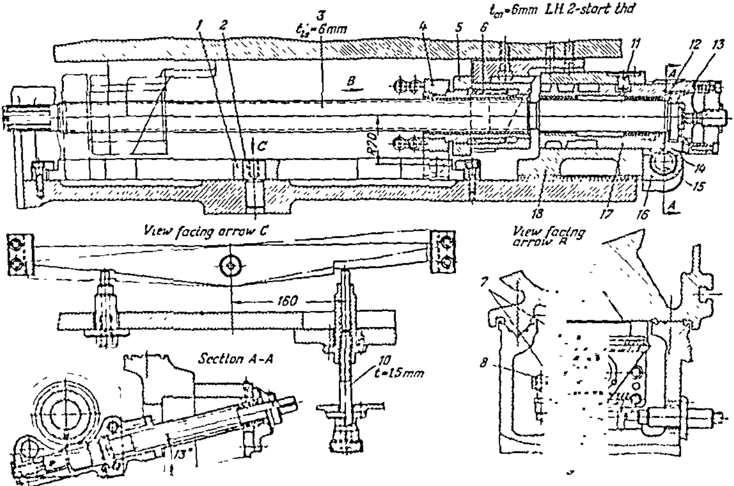


Fig. 321. Pitch compensator and thread matching device of the model 5832 thread grinder:
1—correction bar, 2—pin, 3—lead screw, 4—flange with a lug, 5—housing, 6—nut, 7—springs, 8—hose for lubricating the nut, 9—ball, 10—pitch compensator screw, 11—pin, 12 and 13—bronze thrust washers, 14—worm wheel, 15—worm, 16—worm bearing housing, 17—sleeve, 18—sleeve housing

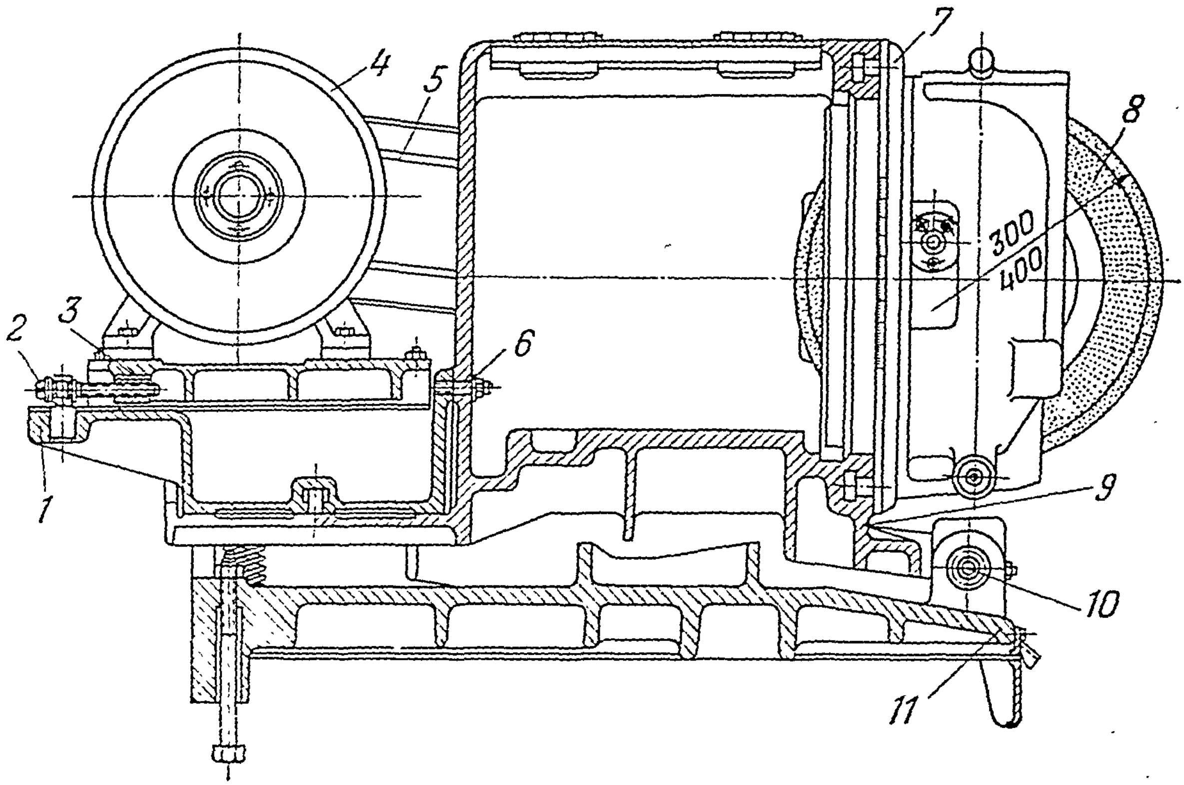


Fig. 322. Wheelhead of the thread grinder, model 5Б82:
1—bracket; *2*—screw for adjusting belt tension; *3*—motor base; *4*—electric motor; *5*—belt drive; *6*—pivot pin of the bracket and motor base; *7*—swivelling wheel spindle housing; *8*—grinding wheel; *9*—wheelhead housing; *10*—pivot of the wheelhead; *11*—wheelhead slide

The wheel spindle runs in precision sleeve bearings. Spindle speeds are infinitely variable.

The wheelhead (housing *9*) is mounted on slide *11* which is advanced to and withdrawn from the line of centres of the grinder on transverse ways of the base (see Fig. 317*b*), but also has a rocking motion (see Fig. 317*c*).

Thus, the following motions are imparted to the wheelhead:

(1) Crosswise travel along the transverse ways is a positioning motion intended for coarse infeed and for advancing the wheelhead to a definite and exact position. It is also used to compensate for wheel wear due to dressing.

(2) The rocking motion of the wheelhead is used for relieving, for rapid approach and withdrawal of the wheel, for fine "micron" infeeds, and for infeed in grinding taper threads.

The *infeed and wheel-dressing compensator mechanism* is shown in Fig. 323. The screw and nut of this mechanism have the following functions: hand

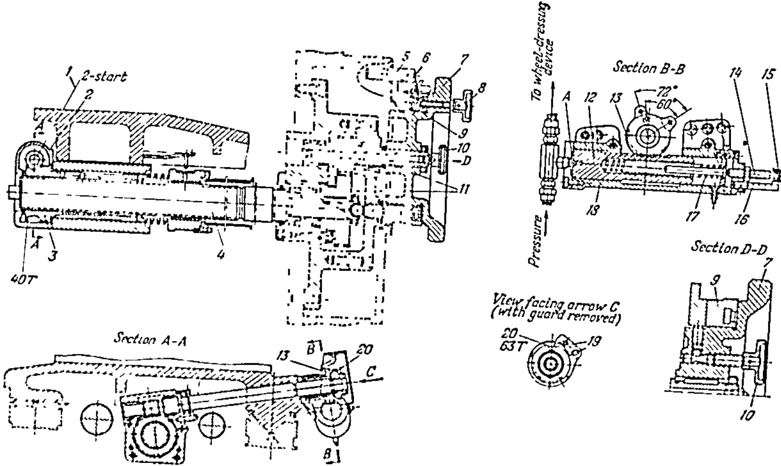


Fig. 323. Infeed and wheel-dressing compensator mechanism:

1—worm; 2—worm housing; 3—nut; 4—screw; 5—positive stop; 6—hinged dog; 7—wheelhead infeed handwheel; 8 and 10—knobs; 9—dial ring; 11—gearing; 12—plunger and rack; 13—segment gear; 14—stop screw; 15—head; 16—scale; 17—spring; 18—hydraulic cylinder; 19—pawl; 20—ratchet wheel

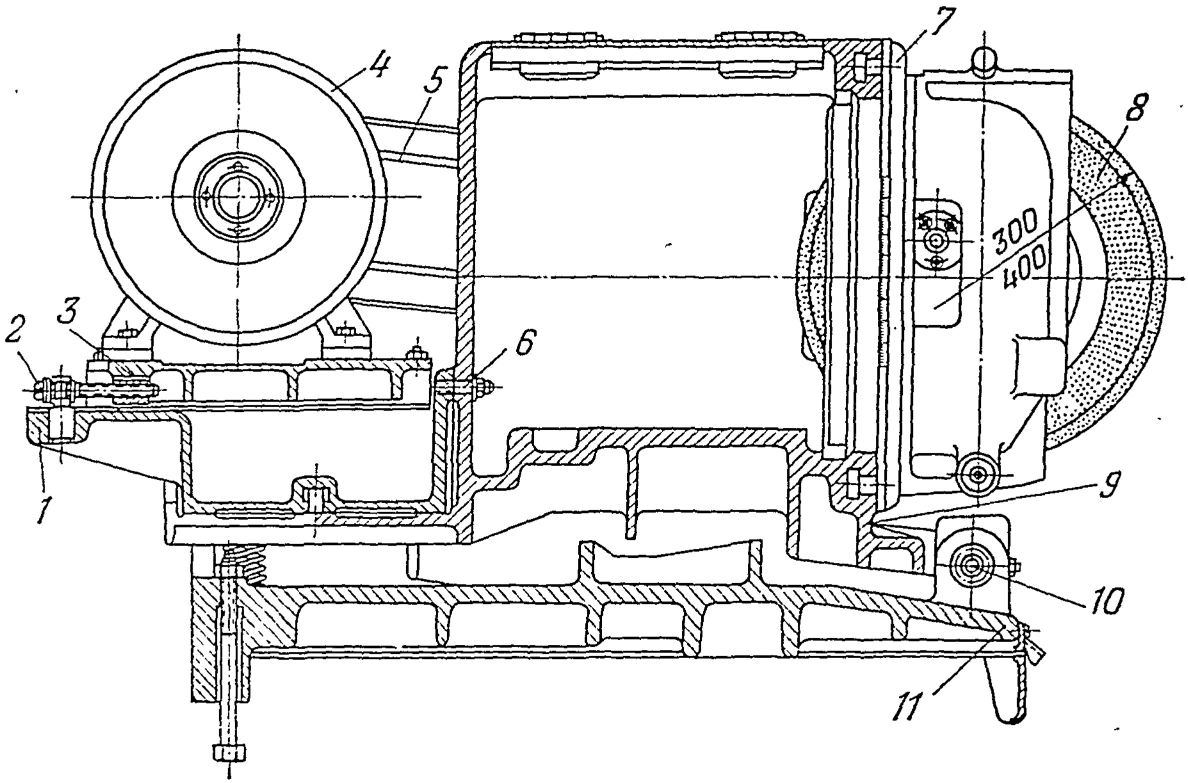


Fig. 322. Wheelhead of the thread grinder, model 5Б82:
1—bracket; *2*—screw for adjusting belt tension; *3*—motor base; *4*—electric motor; *5*—belt drive; *6*—pivot pin of the bracket and motor base; *7*—swivelling wheel spindle housing; *8*—grinding wheel; *9*—wheelhead housing; *10*—pivot of the wheelhead; *11*—wheelhead slide

The wheel spindle runs in precision sleeve bearings. Spindle speeds are infinitely variable.

The wheelhead (housing *9*) is mounted on slide *11* which is advanced to and withdrawn from the line of centres of the grinder on transverse ways of the base (see Fig. 317*b*), but also has a rocking motion (see Fig. 317*c*).

Thus, the following motions are imparted to the wheelhead:

(1) Crosswise travel along the transverse ways is a positioning motion intended for coarse infeed and for advancing the wheelhead to a definite and exact position. It is also used to compensate for wheel wear due to dressing.

(2) The rocking motion of the wheelhead is used for relieving, for rapid approach and withdrawal of the wheel, for fine "micron" infeeds, and for infeed in grinding taper threads.

The *infeed and wheel-dressing compensator mechanism* is shown in Fig. 323. The screw and nut of this mechanism have the following functions: hand

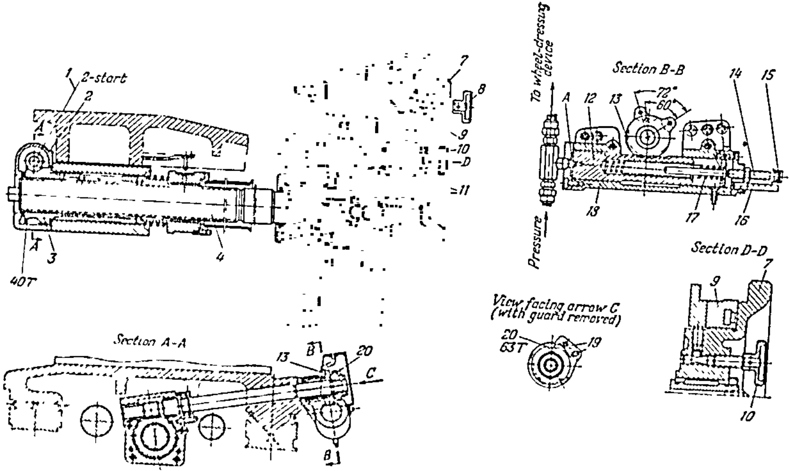


Fig. 323. Infeed and wheel-dressing compensator mechanism:

1—worm, 2—worm housing, 3—nut, 4—screw, 5—positive stop, 6—hinged dog, 7—wheelhead infeed handwheel, 8 and 10—knobs, 9—dial ring, 11—gearing, 12—plunger and rack, 13—segment gear, 14—stop screw, 15—head; 16—scale, 17—spring, 18—hydraulic cylinder, 19—pawl, 20—ratchet wheel

gear ratio is

$$X_2 = \frac{a}{b} \times \frac{c}{d} = \frac{2z}{15}$$

The basic displacements in relief grinding work with helical flutes are

$$1 \text{ revolution of the work} \rightarrow z\left(1+\frac{t}{P}\right) \text{ revolutions of the cam}$$

where t = pitch of the thread being ground
P = lead of the helical flutes.

The helical angle of the thread is equal to the angle of inclination of the flutes. Therefore

$$t = \pi d_p \tan \alpha \quad \text{and} \quad P = \pi d_p \cot \alpha$$

where d_p is the pitch diameter of the thread.

Then

$$z\left(1+\frac{t}{P}\right) = z\,(1+\tan^2 \alpha)$$

from which it is evident that the formula for the ratio of the change gears for this case is obtained from the formula given above to determine X_2 if the factor $1 + \tan^2 \alpha = \frac{1}{\cos^2 \alpha}$ is introduced in the right-hand side. Thus

$$X_2 = \frac{a}{b} \times \frac{c}{d} = \frac{2z}{15 \cos^2 \alpha}$$

The grinding wheel is set to the helix angle of the thread by swivelling the spindle unit with spindle housing *7* (Fig. 322). This complies with the arrangement shown in Fig. 316*b*.

Dressing a single-ribbed wheel. Special devices are employed to true the grinding wheel to the profile of the thread being ground and to maintain this profile by subsequent dressing.

Automatic wheel-dressing devices for single-ribbed wheels have three diamonds, two of which dress the flanks and the third dresses the apex of the wheel. The gearing diagram of the wheel-dressing device is illustrated in Fig. 325.

Worm *3*, driven from an electric motor (0.175 kW, 1,430 rpm) through change gears *1* and worm gearing *2*, transmits rotation to worm wheel *3′*. A crank pin secured in this worm wheel slides along the slot of rocker arm *14*. Upon rotation of worm wheel *3′*, arm *14* rocks about shaft *12*, oscillating gear *11* through one-fourth of a revolution. This oscillating motion reciprocates sliding bars *7* and *10* through gear *5*, meshing with drive gear *11*, and pinions *4* and *6* which mesh with racks cut on the sliding bars.

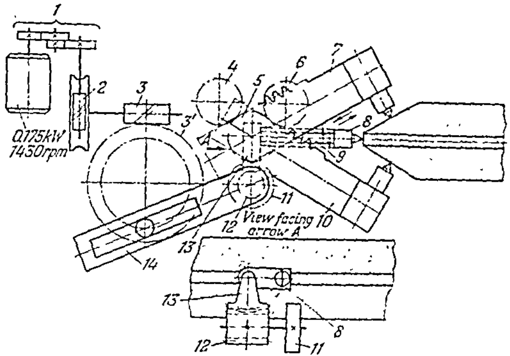


Fig. 325. Gearing diagram of the single-rib wheel dresser

The flank diamond holders are clamped in sliding bars 7 and 10.

Helical teeth cut on shaft 12 of rocker arm 14 mesh with the crossed helical segment gear 13. Arm 8, carrying the apex diamond, is fastened on shaft 9 of the segment gear. Sliding bars 7 and 10 and arm 8 make one full stroke (back and forth) for each revolution of worm wheel 3'. The slotted rocker arm mechanism reduces the speed of diamond travel at the beginning (and end) of the stroke. This prevents the chipping of the sharp edge of the wheel in truing and dressing.

The electric motor powering this device stops automatically after one full stroke.

When a special button is pressed, the dressing device is fed by hydraulic means toward the grinding wheel and the wheelhead is fed toward the work. These amounts of infeed are strictly equal and can be varied in a range from 0.01 to 0.04 mm (see Section B-B in Fig 323) This device enables the wheel to be dressed without altering the work size since it readjusts the distance between the work and wheel axes to compensate for the lessened diameter of the grinding wheel that will exist after dressing

Wheel speed in the dressing operation is only one half of that used in grinding threads.

19-3. Universal Thread-Grinding Machine, Model 5822

Purpose and design features. This thread grinder (Fig. 326) is intended for performing all the main thread-grinding operations required in the tool rooms of engineering plants. These include the grinding of straight and taper thread gauges, precision screws and worms; relief grinding of taps, fine-module hobs and thread-milling cutters; grinding crusher rolls for dressing multiribbed thread-grinding wheels and other formed wheels; grinding circular thread chasers, tangent and radial chasers for die heads, precision gear racks, etc.

Thread can be ground by three methods:

(1) Traverse grinding with a single-rib or multiribbed wheel in one direction with an automatic stop at the end of the table stroke and rapid return.

(2) Traverse grinding with a single-rib or multiribbed wheel in both directions:

(a) in one pass with automatic or manually controlled table stop at the end of each stroke, the first workpiece being ground with traverse to the right, the second with traverse to the left; the third to the right again, etc.;

(b) in several passes with automatic table reversal at the end of each stroke.

(3) Plunge-cut grinding with a multiribbed wheel with power infeed to the full depth or to a part of the depth (grinding in one or several revolutions of the work).

In grinding by the first method, the cycle begins with rapid approach of the wheel to the work, and the starting of the work head drive and the coolant pump. At the end of the working traverse, the table is stopped automatically by adjustable dogs. Next levers are shifted (Fig. 326) to rapidly retract the wheel from the work, and to engage the coarse-pitch unit (for rapid traverse). Then the table is reversed and stops automatically when it returns to the initial position.

When thread is ground in both directions, the table is automatically reversed at each end of the stroke by adjustable dogs which reverse the drive motor.

Plunge-cut grinding is applied for work on which the length of the thread does not exceed 36 mm (the wheel face width being 40 mm).

Thread of the 1st and 2nd accuracy grades can be efficiently ground. Relief grinding is done on table travel in one direction. At the end of the stroke, the wheel is retracted and rapid table return is engaged.

The model 5822 grinder has the following distinctive features:

1. The work spindle is powered from a d-c electric motor with infinitely variable speeds, supplied from a rotary amplifier (*RA*) with a wide range of regulation.

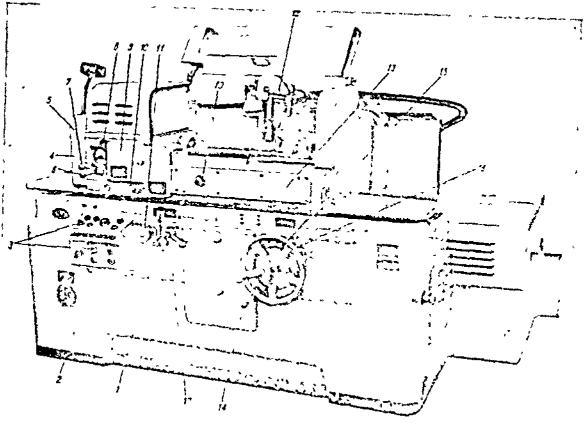


Fig. 326. Universal thread-grinding machine, model 5822.

1—lever for starting, reversing and stopping the table and work spindle, 2—base 3—motor control push-button panel, 4—workhead 5—pitch and differential [illegible] for engaging the relieving [illegible] indicator (tachometer), [illegible] for pitch compensation, [illegible] matically stopping the [illegible] and retraction of the wh[illegible] [illegible] the infeed d[illegible] 11—lever f[illegible]

2. Wheel spindle speed is changed by means of change pulleys. This considerably simplifies the construction of this unit and enables a constant peripheral speed of the wheel to be maintained (within definite limits) notwithstanding wheel wear and the consequent reduction in wheel diameter.

3. The design incorporates a differential gear unit enabling workpieces with helical flutes to be relief ground with a high degree of accuracy.

4. All crosswise travel of the wheelhead is accomplished by mechanisms that are not based on hydraulic action. The wheelhead travels along efficient roller ways (without tilting).

Data on the model 5822 thread grinder follow:

Brief Specifications

Height of centres, mm	100
Distance between centres, mm	500
Diameter of threads ground, mm:	
with a single-rib wheel	2 to 150
with a multiribbed wheel	4 to 120
Pitch of threads ground, mm:	
V-threads:	
with a single-rib wheel	0.25 to 24
with a multiribbed wheel	1 to 4
Trapezoidal threads	2 to 24
Number of starts ground	1, 2, 3, 4, 6, 8, 12 and 24
Range of wheel spindle speeds, rpm	1,440 to 2,660
Range of infinitely variable work spindle speeds, rpm	0.3 to 45
Work spindle speed during rapid table return, rpm	100
Attainable thread accuracy (using single-rib wheel), mm:	
Thread pitch error (pitches up to 8 mm):	
over a length of 25 mm	within ± 0.003
over a length of 400 mm	within ± 0.008
Pitch diameter error	within ± 0.003
Half angle of thread error	within $\pm 5'$

Gear trains and construction of the grinder units. All the principal units (Fig. 326) are mounted on the rigid cast-iron base. The controls are conveniently arranged at the front of the base. The table and wheelhead travel along roller ways—a feature that contributes substantially to the sensitivity of the systems.

The *work spindle and table drive* (Fig. 327) is powered from an electric motor (0.45 kW, 1,430 rpm) mounted on the workhead cover and supplied by a rotary amplifier. Rotation is transmitted through a V-belt drive $\frac{78\ \text{dia}}{172\ \text{dia}}$ and worm gearing $\frac{2}{36}$ to a cluster gear and further, through backlash compensator *14*, to the work spindle. The lead screw is driven from the cluster gear through gears $\frac{60}{60}$ or $\frac{96}{24}$ and pitch change gears *13*.

In grinding thread with a pitch up to 8 mm, the table is driven through gears $\frac{60}{60}$. The coarse-pitch unit *11* $\left(i=\frac{96}{24}\right)$ provides a fourfold increase in pitch and is used to grind threads of larger pitch and for rapid return motions.

The provision of backlash compensator *14* on the spindle enables thread to be ground in both directions.

The grinder is set up to the pitch of the thread to be ground by means of change gears. A correction bar enables the pitch or lead of the thread to be increased or decreased by 0.2 per cent. For example, in grinding spur gear hobs, the axial pitch is a fractional value depending upon the helix angle of the hob thread, and it is difficult to obtain the exact pitch with change gears alone. A pitch within the specified accuracy can be readily ground if the correction bar is also made use of. The lead screw and the correction bar mechanism are arranged in the lower part of the base. The lead screw nut (Fig. 327) has additional external thread and is screwed into a housing linked to the base. Before beginning to grind the thread, a screw with a dial (*11* in Fig. 326 and *9* in Fig. 327) is turned to shift the housing with the nut and, consequently, the lead screw and work table, in reference to the base until the preformed thread is matched with the wheel.

The *relieving and plunge-cut mechanism* is driven in the following manner. Rotation is transmitted from shaft *I* of the work spindle drive (Fig. 327) through gears $\frac{30}{45}$ and a differential gear with a ratio $\frac{1}{2}$ to shaft *II* and further through relieving change gears *10*, gears $\frac{20}{20}$, shaft *III*, bevel gearing $\frac{25}{25}$ and spur gears $\frac{26}{26}$ to shaft *IV*. This shaft carries either interchangeable relieving cam *3* or the cam providing plunge-cut feed of the grinding wheel. The construction of this mechanism enables the following crosswise motions of the wheelhead to be effected:

(1) manually operated movements. (a) slow positioning motion for initially setting up the wheelhead to suit the diameters of the work and grinding wheel; (b) rapid approach and withdrawal of the wheel over a definite distance; (c) fine (micron) infeed of the wheel to obtain the required work size,

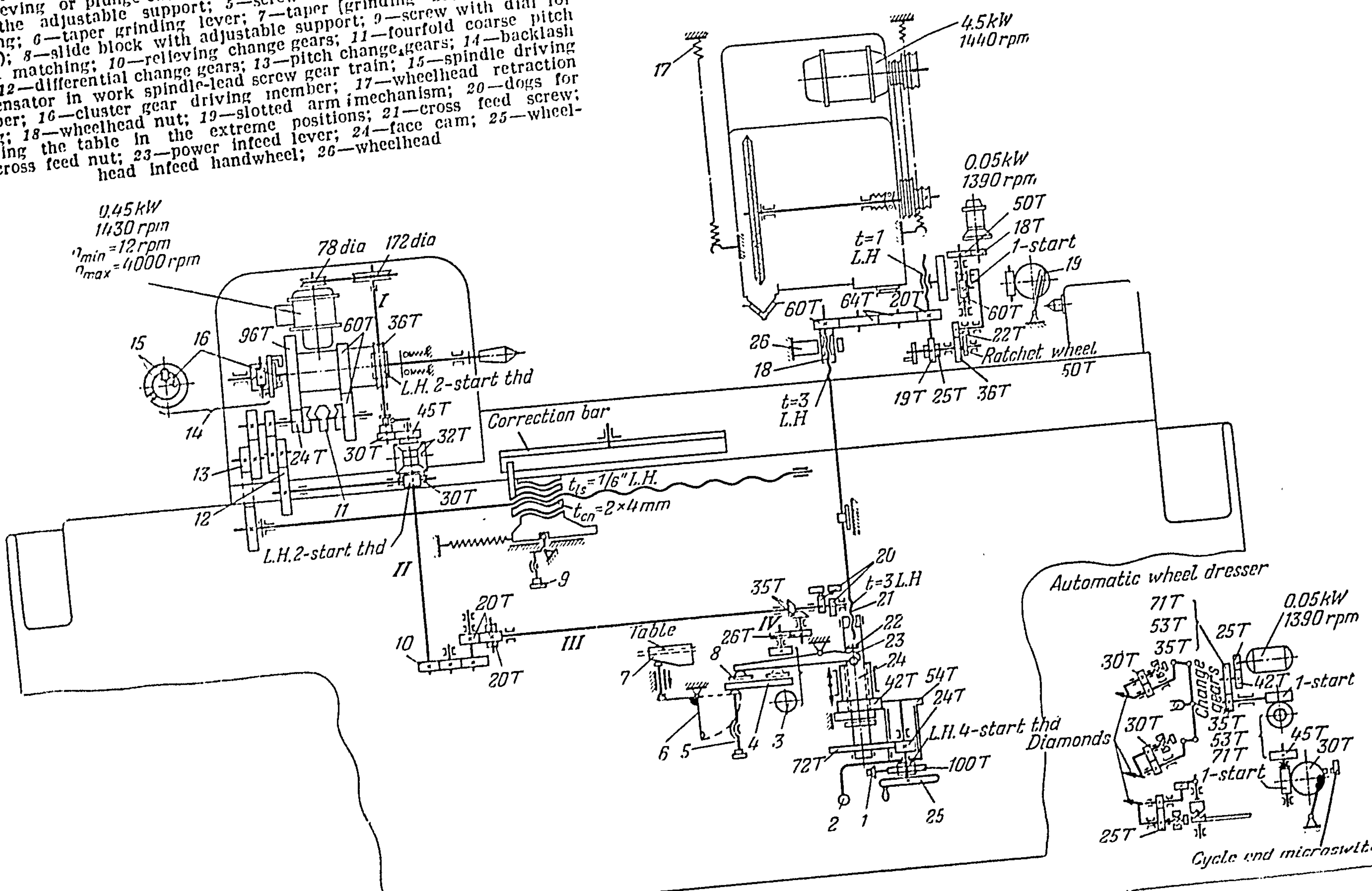
(2) power-operated movements: (a) plunge-cut feed; (b) in relief grinding; (c) in taper thread grinding

The *wheelhead is positioned with slow traverse* by hand by turning handwheel *25* (Fig. 327). This rotates nut *22* through gears $\frac{24}{12}$ Cross feed screw *21* is integral with a shaft which is linked to a bracket, secured on the base, through a yoke with a feather.

Thread is also cut on the other end of the shaft This thread is screwed into nut *18* which is fastened to the wheelhead housing Therefore, when

Fig. 327. Gearing diagram of the model 5822 thread-grinding machine:

1—micron infeed knob and dial; 2—rapid wheelhead retraction lever; 3—relieving or plunge-cut feed cam; 4—lever with slide block carrying the adjustable support; 5—screw for disengaging taper thread grinding; 6—taper grinding lever; 7—taper (grinding bar (interchangeable); 8—slide block with adjustable support; 9—screw with dial for thread matching; 10—relieving change gears; 11—fourfold coarse pitch unit; 12—differential change gears; 13—pitch change gears; 14—backlash compensator in work spindle-lead screw gear train; 15—spindle driving member; 16—cluster gear driving member; 17—wheelhead retraction spring; 18—wheelhead nut; 19—slotted arm mechanism; 20—dogs for stopping the table in the extreme positions; 21—cross feed screw; 22—cross feed nut; 23—power infeed lever; 24—face cam; 25—wheelhead infeed handwheel; 26—wheelhead



handwheel *25* is rotated, screw *21* moves axially, traversing the wheelhead, since the screw is held by the feather against rotation.

The amount of cross travel is read off on a dial. The wheelhead is fed 0.005 mm if handwheel *25* is turned one dial division. The wheelhead is fed to a positive stop if a batch of identical workpieces is to be ground.

Rapid wheel approach and withdrawal are accomplished by turning lever *2* (Fig. 327). This rotates gear *54T* which meshes with wide-face gear *42T*. The teeth of the latter are cut on the body of face cam *24*. Cam *24* is fitted on nut *22* and its profile is in contact with the rollers of lever *23* when lever *2* is turned. In this case, the rollers act as rests for cam *24*, upon which it bears in moving the wheelhead together with screw *21*. This contact is maintained by the action of spring *17* which serves to retract the wheelhead. A maximum movement of 6 mm is available for rapid retraction.

Fine (*micron*) *infeed* of the wheelhead is provided by the slow motion mechanism. The latter is operated by rotating micron infeed knob *1*. Rotation is transmitted to nut *22* through a worm and worm gear $\left(\text{ratio } i = \frac{1}{100}\right)$, fastened to handwheel *25* in this case. The dial of the micron infeed knob has 50 divisions. The wheelhead is fed 0.0025 mm per division and 0.125 mm per revolution of the dial.

The power crosswise movement of the wheelhead in relief grinding (relieving motion), in plunge-cut grinding, as well as in grinding taper thread, is accomplished by axial motion of cam *24*, as in rapid hand retraction.

Power *infeed in plunge-cut grinding* is effected by the action of cam *3* mounted on shaft *IV* (Fig. 327) which is driven from shaft *I* of the work spindle drive through relieving change gears *10*. Screw *5*, in this case, is advanced to provide a support for lever *4*, and the bar for taper thread grinding is removed. The rotation of cam *3* is transmitted through a roller, lever *4* and slide block *8* to lever *23*. The action of the rollers of lever *23* on the face cam *24* provides the wheelhead infeed.

The unit is set up for a given depth of grinding in the pass by adjustment of slide block *8* with the adjustable support along lever *4* to the required scale graduation. *Relief grinding* is performed by installing a relieving cam in place of cam *3* for plunge-cut grinding. Two interchangeable cams are furnished with the grinder. One is for a relief of 0.02 to 0.3 mm (on taps) and the other for a relief of 0.3 to 4 mm (on milling cutters and hobs). Work is relief ground with table travel in one direction.

Workpieces with multiple-start thread can be relief ground only under the condition that the number of flutes is a multiple of the number of starts. An indexing head is used to index the work from start to start.

Workpieces with helical flutes are relief ground by installing the required change gears on the differential quadrant *12*. Through worm gearing $\frac{1}{...}$, and

bevel gears, the differential gear transmits the increment rotation to the T-shaped shaft and, therefore, to shaft *II* whose extension it is.

In *taper thread grinding* one of the interchangeable taper bars *7* is clamped in a slot of the work table. Screw *5* is retracted as far as it will go.

Upon table travel, a sliding bar, whose rollers contact taper bar *7* and whose other end bears upon one arm of lever *6*, actuates the lever system which effects axial movement of nut *22*. The maximum taper of the thread that can be ground is 1 : 5. Thus, taper threads are ground by a combination of longitudinal traverse of the table and cross feed of the wheelhead.

The *dresser control and wheel-dressing compensator mechanism* is powered by a 0.05-kW electric motor running at 1,390 rpm (Fig. 327).

The infeed of the dresser slide is effected by a screw with a pitch of $t = 1$ mm. This screw is rotated from the motor through gears $\frac{18}{50}$, worm gearing $\frac{1}{60}$, slotted rocker arm mechanism *19*, gears $\frac{22}{26}$, a ratchet mechanism and gears $\frac{19}{25}$. Dresser slide infeed is motored and is disengaged after one full stroke of the rocker arm and one working stroke of the ratchet pawl. The rate of infeed is determined by the number of ratchet wheel teeth engaged by the pawl in each stroke.

Simultaneously, rotation is transmitted from the screw through a system of gearing $\left(\text{ratio } i = \frac{20}{60}\right)$ to nut *18*, thereby providing infeed of the wheelhead to compensate for wheel wear in dressing.

The *dressing motion of the diamonds* is powered by another electric motor (0.05 kW, 1,390 rpm). The reciprocating motion is imparted to the diamonds through change gears, two sets of worm gearing, $\frac{1}{45}$ and $\frac{1}{30}$, a slotted arm mechanism and a system of levers. The speed of diamond travel is set up with change gears.

Setting Up the Thread Grinder (Fig. 327)

1. Setting up to the pitch (or lead) of the thread to be ground.

The basic displacements are

$$1 \text{ revolution of the work} \rightarrow t_{th}$$

where t_{th} is the pitch (or lead) of the thread to be ground.

The corresponding gear train equation is

$$1 \times i_0 i_x \, t_{ls} = t_{th}$$

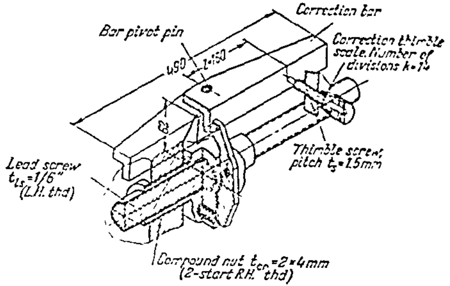


Fig. 328. Correction bar

where $i_0 = \frac{60}{60} = 1$ for standard pitches and

$i_0 = \frac{96}{24} = 4$ for coarse pitches

i_x = ratio of the pitch change gears (item *13* in Fig. 327)

$t_{ls} = \frac{1''}{6}$ = pitch of the lead screw.

Hence

$$i_x = \frac{6}{25.4} \times \frac{t_{th}}{i_0} = \frac{30}{127} \times \frac{t_{th}}{i_0}$$

2. **Setting up the correction bar.** The correction bar is resorted to in cases when it is impossible to select a set of change gears with a sufficiently accurate ratio i_x, or when it is necessary to compensate for accumulated error in the pitch of the thread being ground or of the lead screw thread.

Figure 328 illustrates the construction of the correction bar employed in the model 5822 grinder. This bar is set to a thimble scale.

The increment travel is imparted to the table through a compound nut of this mechanism which increases the amount of correction. The required angle of inclination of the bar is determined from the formula

$$\tan \beta = \frac{\Delta l}{l} \times \frac{2\pi R}{t_{ls} \cdot t_{cn}}$$

where ΔL = increment travel of the table due to bar inclination, mm
L = length of thread being ground, mm
$t_{ls} = \frac{1''}{6}$ = pitch of the lead screw (L.H. thd)
$t_{cn} = 2 \times 4$ mm = lead of the compound nut (2-start R.H. thd)
$R = 62$ mm = effective length of the nut-turning lever.

The correction bar is set to an angle β by turning the thimble the required number of divisions k_1. Therefore

$$\tan \beta = \frac{t_s k_1}{kl}$$

where $t_s = 1.5$ mm = pitch of the thimble screw
$k = 14$ = number of divisions on the thimble scale
$l = 160$ mm = distance from the bar pivot pin axis to the thimble screw axis.

It follows from the two equations for $\tan \beta$ that

$$\frac{\Delta L}{L} \times \frac{2\pi R}{t_{ls} + t_{cn}} = \frac{t_s k_1}{kl}$$

hence

$$\frac{\Delta L}{L} = \frac{k_1 t_s}{kl} \times \frac{t_{ls} + t_{cn}}{2\pi R}$$

If the thimble is turned one division ($k_1 = 1$) the amount of correction introduced in the accumulated pitch error over a length of $L = 100$ mm will be

$$\Delta L = L \frac{t_s}{kl} \times \frac{t_{ls} + t_{cn}}{2\pi R}$$

After substituting the corresponding values we obtain

$$\Delta L = 100 \frac{1.5}{14 \times 160} \times \frac{\frac{25.4}{6} + (4 \times 2)}{2\pi \times 62} \cong 0.002 \text{ mm} = 2 \text{ microns}$$

3. Setting up the relieving change gears.

(a) In relieving a cutting tool with straight flutes, the basic displacements are

1 revolution of the work $\rightarrow z$ revolutions of the cam

where z is the number of teeth (or flutes) on the tool being relieved.

The gear train equation is

$$1 \times \frac{36}{2} \times \frac{28}{42} \times i_{dif} \times i_y \times \frac{20}{20} \times \frac{35}{35} \times \frac{26}{26} = z$$

where i_y = ratio of the relieving change gears (item *10* in Fig. 327).

Substituting $i_{dif} = \frac{1}{2}$ (transmission to the T-shaped shaft), we obtain

$$i_y = \frac{z}{6}$$

(b) In relief-grinding tools with helical flutes, an increment reciprocation is transmitted to the wheelhead through the differential change gears and the differential gearing in addition to its main motion.

The additional motion per revolution of the work is determined by the basic displacements

$$1 \text{ revolution of the work} \rightarrow \frac{z t_{th}}{P_{hf}} \text{ revolution of the cam}$$

where P_{hf} is the lead of the helical flutes.

In this case, the gear train equation is

$$1 \times i_0 \times i_{y'} \times \frac{2}{30} \times i_{dif} \times i_y \times \frac{20}{20} \times \frac{35}{35} \times \frac{26}{26} = \frac{z t_{th}}{P_{hf}}$$

where $i_{y'}$ is the ratio of the differential change gears (item *12* in Fig. 327). Then

$$i_{y'} = \frac{15 z t_{th}}{i_0 i_{dif} i_y P_{hf}}$$

Substituting $i_y = \frac{z}{6}$ and $i_{dif} = \frac{1}{2}$ (transmission to the T-shaped shaft), we obtain

$$i_{y'} = \frac{15 z t_{th}}{i_0 P_{hf} \frac{1}{2} \times \frac{z}{6}} = \frac{180 t_{th}}{i_0 P_{hf}}$$

Construction of the wheelhead (Fig. 329). The grinding wheel is set to the helix angle of the thread to be ground by swivelling the wheel spindle housing in the same way as in the model 5K822 grinder.

Spindle 1 (Fig. 330) runs in two thin-walled bimetallic bearings 3. The spindle journals are embraced by three pads, spaced at 120° and projecting along the whole length of the tapered surface of the bearing liners, when nuts *6* are tightened. The bearings are pressure-lubricated from a gear-type pump. Lubricant is delivered into the bearing before the spindle begins to rotate, *thereby ensuring fluid friction conditions, not only during regular operation,* but during the acceleration of the spindle as well. If a failure occurs in lubricant delivery, the wheel drive motor is automatically switched off. Kerosene with a small addition of oil *(10 to 15 per cent)* is used as the lubricant.

Bearings *3* are fitted with their external tapered surfaces into the tapered bores of sleeves *4* which are press-fitted in housing *5*. The spindle is located in the axial direction by thrust ring *2* against which the spindle flange bears. The face surfaces *of the spindle flange and sleeve are strictly square* to the spindle axis and are carefully lapped. The application of unilateral

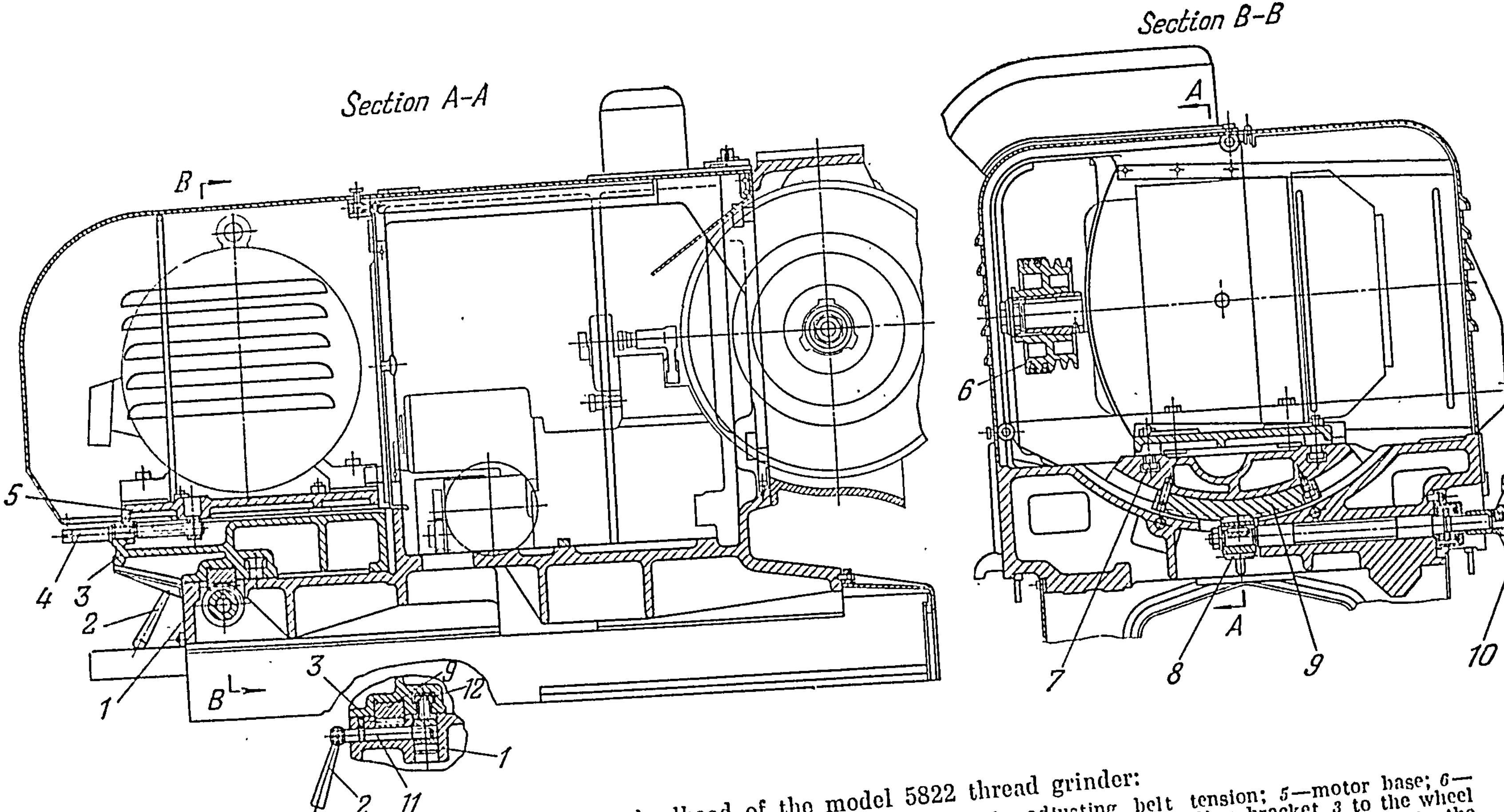


Fig. 329. Wheelhead of the model 5822 thread grinder:

1—wheelhead housing; 2—lever for clamping the bracket; 3—bracket; 4—screw for adjusting belt tension; 5—motor base; 6—driving pulley; 7—T-bolts for clamping the motor base; 8—worm; 9—segment worm wheel for swivelling bracket 3 to the wheel setting angle; 10—handwheel for swivelling the bracket; 11—eccentric shafts; 12—members for clamping the bracket to the wheelhead housing

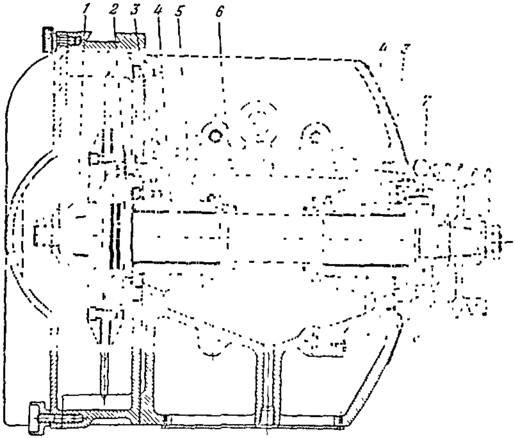


Fig. 330. Wheel spindle of the model 5822 thread grinder

thrust through bearing 7, developed by the action of springs 8, is permissible in this case because the spindle is subjected to almost negligible forces in grinding.

Attachments

The thread grinder is furnished with several attachments. These include a device for dressing single-rib wheels, a crush-form dresser and a profile copying dresser. The internal grinding attachment is used to grind internal threads, as well as for relief grinding hobs and thread-milling cutters in cases when a large wheel cannot be employed.

Precision gear racks, threading chasers, flat thread-rolling dies and tangential die-head chasers are ground with the flat grinding attachment.

A detachable graticule microscope serves to check the wheel profile and to facilitate thread matching in grinding fine threads. The pitch of the thread being ground can be checked directly in the grinder by a special optical indexing device consisting of a precision glass scale and spiral-graticule microscope.

Involute helicoidal worms and worms with a straight flank in either the normal or axial sections can be ground.

The removable universal wheel generating dresser is used to correct the wheel profile in grinding worms.

Squirrel-cage induction motors are used in all drives of the grinder with the exception of the workhead drive. This latter drive is powered by a d-c motor with infinitely variable speeds in a range from 12 to 1,800 rpm (at constant torque), as well as a rapid traverse speed of 4,000 rpm.

The electric circuit provides three modes of operation: setting-up, manually controlled and on a semiautomatic cycle.

CHAPTER 20

THREAD-ROLLING MACHINES

20-1. General

Rolled threads have increased strength and wear resistance over threads produced by cutting due to the cold forging they receive during the rolling process.

Thread-rolling machines operate at exceptionally high rates of production and can form threads of a wide variety, both on solid and hollow parts of *all materials possessing sufficient ductility.*

Three general types of thread-rolling machines are available: reciprocating (flat-die) machines, cylindrical-die machines, and rotary planetary machines having a rotary die and a stationary concave-segment die.

An automatic continuous-action thread-rolling machine using a cylindrical die and an annular die has been designed and developed by the Moscow Machine Tool Engineering Institute.

In the flat-die machines (Fig. 331*a*), one of the two dies reciprocates in reference to the other, stationary die. The stroke of the reciprocating die depends upon the diameter of the thread being rolled since the blank makes one revolution and the thread is completely formed during one stroke.

Cylindrical-die machines (Fig. 331*b*) operate with the following motions in thread rolling, positive rotation of both dies (in a two-die machine) in the same direction and radial motion of one of the dies (rapid approach, infeed and retraction). The full cycle for forming thread on the blank, including thread sizing, takes place during one crosswise stroke of the moving die. *The full thread profile is produced in several revolutions of the blank.*

Cylindrical-die thread rolling has found extensive application in the tool industry, especially for rolling the thread on taps.

The pitch diameter D_p of the die thread is equal to

$$D_p = ad_p$$

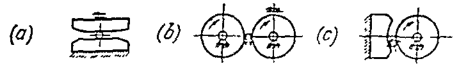


Fig. 331. Die motions in thread rolling

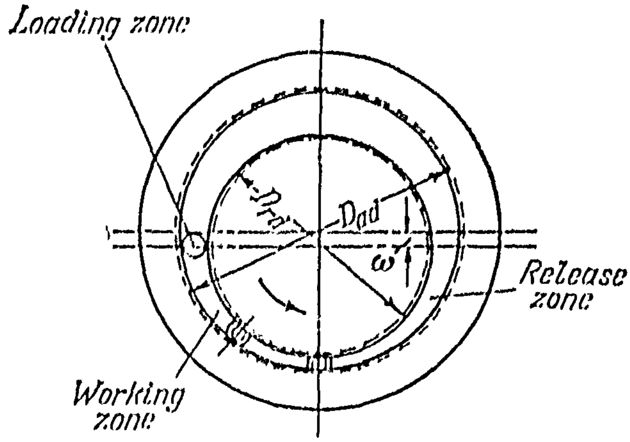


Fig. 332. Diagram of a rotary planetary thread-rolling process using a rotary die and an annular die:
D_{rd}—diameter of the rotary die; D_{ad}—diameter of the stationary annular die; e—eccentricity

where d_p = pitch diameter of the thread on the work being rolled
a = number of starts of the die thread.

Right-hand thread is to be rolled with dies having left-hand thread.

In the rotary planetary machine (Fig. 331*c*) only the central die rotates. A full thread-rolling cycle takes place during the time that the blank passes through the space between the rotary die and the concave-segment die. The length of path is sufficient for the blank to make several revolutions. Machines of this type are not widely used because of the high cost of the tools.

The method of rolling threads between a rotary die and an annular die (Fig. 332) is a continuous process, a highly advantageous feature in comparison with the preceding method. Moreover, an annular die is much easier to make than the concave-segment type (Fig. 331*c*) because it requires no starting bevel at the ends of the thread. The blanks enter at the wider part of the zone between the dies. The thread is rolled on the blank as the latter gradually rolls between the dies as shown in Fig. 332.

20-2. Cylindrical-Die Thread-Rolling Machine, Model 5A935

Purpose. The model 5A935 thread-rolling machine (Fig. 333) is intended for forming threads with cylindrical dies on tap blanks. Thread with a pitch from 1.25 to 3 mm, and a diameter from 8 to 60 mm can be rolled.

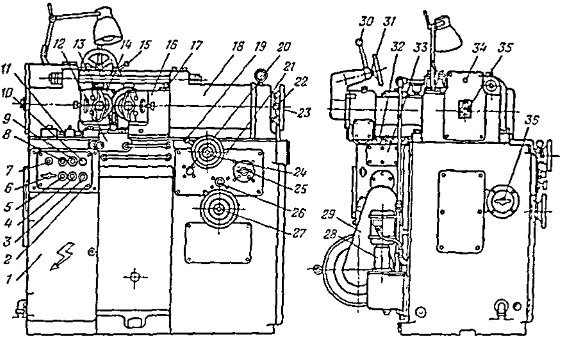


Fig. 333. Cylindrical-die thread-rolling machine, model 5A935:

moving head in-
SUPPLY ON,
CY STOP but-
—work support
for automatic
ing pressure re-
23—handwheel

The maximum permissible rolling force is 10,000 kg. This is sufficient to roll a thread 65 mm long with a pitch of 3 mm, or 120 mm long with a pitch of 1.25 mm.

Design features, hydraulic system and gear trains. The following motions occur in the rolling process:

(1) rotation of the dies mounted on the spindles of the moving and stationary heads;

(2) approach of the moving head to the blank at a variable speed;

(3) die infeed;

(4) dwell (without further infeed), during which the thread is sized; the duration of the sizing period is regulated by setting the time-delay relay;

(5) rapid withdrawal of the moving head to a positive stop.

Three modes of operation are available: manual controls (for setting up), semiautomatic and automatic operation.

The spindles are driven from the speed gearbox whose driving shaft is powered by a 4.5-kW electric motor, running at 1,440 rpm, through a V-belt transmission $\frac{100 \text{ dia}}{134 \text{ dia}}$ (Fig. 334).

Two cluster gears *21* and *22* (Figs. 334 and 335), sliding along shaft *II*, can be brought into mesh with the corresponding gears mounted rigidly on shaft *I*. This enables four different speeds to be transmitted to driving gear *20*.

Gears *16* and *17* are freely mounted on shaft *III*. Intermediate gear *17* meshes with gears *12* and *20* to transmit rotation to driving shaft *V* of the stationary head spindle. Rotation is transmitted to gear *16*, freely mounted on shaft *III*, from gear *17* through friction disks *2* and *3* (Fig. 335). Friction disk *2* is keyed to shaft *III*, while disk *3* is linked to this shaft by dowel pin *4*, press-fitted into the hub of the disk and passing through a milled slot in shaft *III*. Through sliding friction disk *3*, cup (Belleville) springs *5* force gears *16* and *17*, separated by spacer ring *1*, against stationary friction disk *2*.

Cup springs *5* are adjusted by nut *6* so that the gears *16* and *17* transmit the required torque. Gear *16* meshes with gear *13* mounted on driving shaft *IV* of the moving head.

Rotation is transmitted from driving shafts *IV* and *V* through flexible couplings *10* and *11*, connecting shafts *6* and *9*, flexible couplings *3*, *7* (Fig. 334) and *23* (Fig. 335), and worm gearing units *2*, *1*, *4* and *5* to spindles *VI* and *VII* of the stationary and moving heads.

The flexible spindles compensate for misalignment of the units in reference to each other, which may in part be due to swivel of the stationary head to align the spindle axes.

Connecting shaft *9* (Fig. 334) has a splined section, sliding in sleeve *8* and thus permitting travel of the moving head.

In setting up the machine it may be necessary to turn one die in relation to the other so that the thread ridges of one are opposite either the ridges or thread grooves of the other, depending upon the number of starts being rolled. This adjustment is made with the aid of planetary gearing provided in the drive mechanism.

Sun gear *15* (Figs. 334 and 335) of the planetary gearing is secured on shaft *III* and meshes with planet gear *14* which, in turn, meshes with the internal teeth of gear *17*. Axle *8* of planet gear *14* is fixed in gear *16* (Figs. 334 and 335).

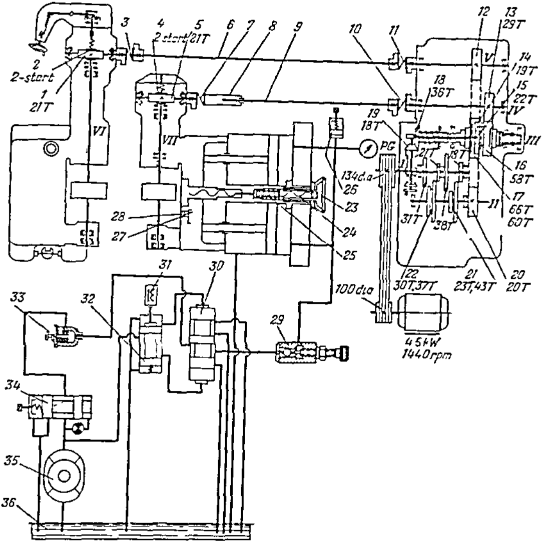


Fig. 334. Combined hydraulic circuit and gearing diagram of the thread-rolling machine, model 5A935

To turn one die in relation to the other, it is necessary to turn gear *16* in relation to gear *17*. This is done by turning lever *31* and, with it, eccentric *26* (Fig. 335). This shifts shaft *25*, compressing spring *24*, so that the clutch teeth on the shaft end engage those on the end of shaft *III*. At the same time,

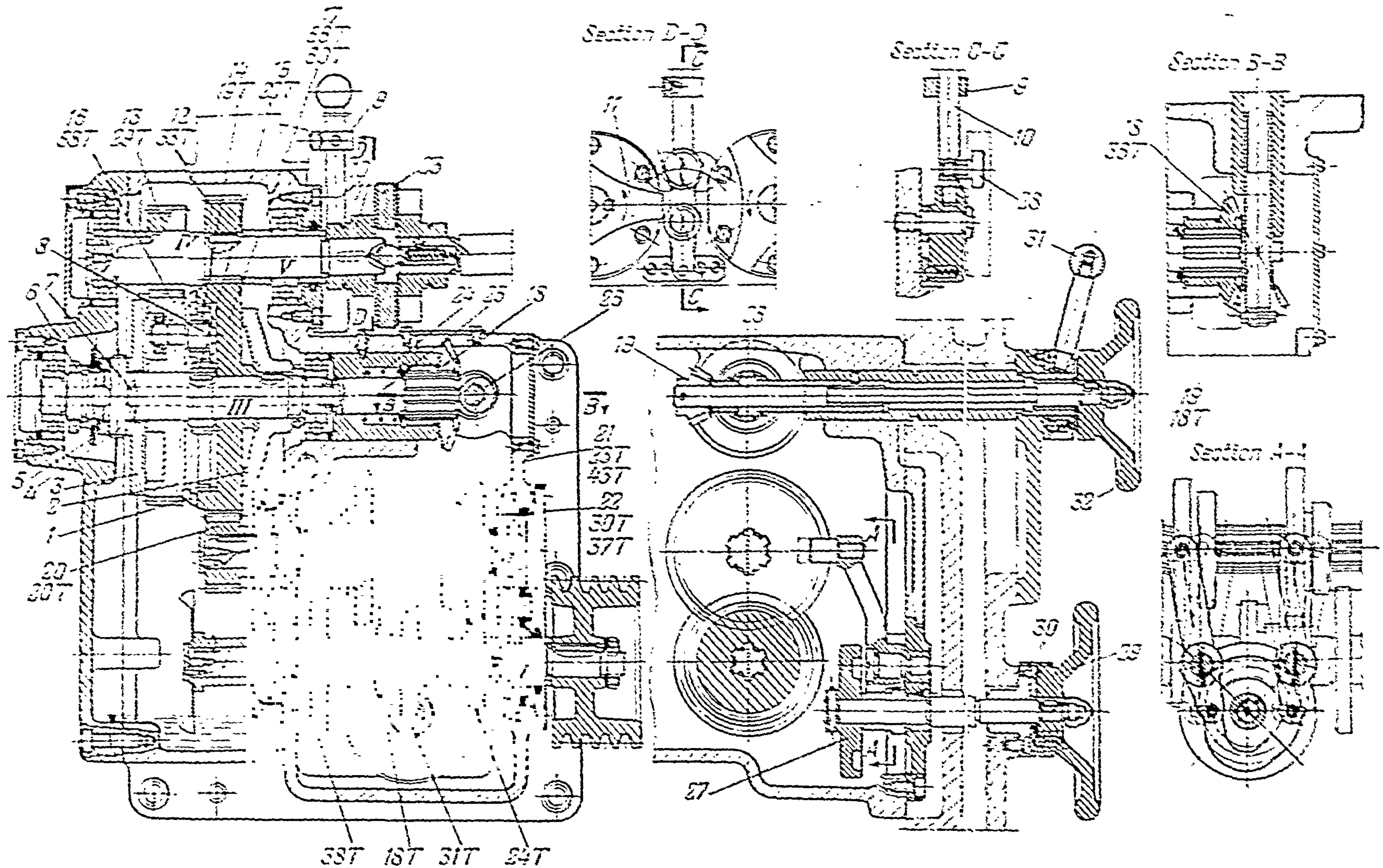


Fig. 335. Spindle drive reducing gear in the model 5A935 thread-rolling machine

the bottom of the recess in the end of shaft *25* shifts pusher rod *7*, located in the hole of shaft *III*, so that it moves back friction disk *3*, acting through pin *4* and compressing cup springs *5*.

To turn one of the gears, the other must be retarded. This is accomplished by shifting lever *10* to the corresponding (R.H. or L.H.) position (Fig. 335, Sections *D-D* and *C-C*) so that a lug on either of the clutch members *11*, mounted on shaft *IV* or *V*, runs up against stop *28* screwed into lever *10*.

Rotation is transmitted from handwheel *32* (Fig. 335) through bevel gears *19* and *18* (Figs. 334 and 335) to shaft *III* and sun gear *15* of the planetary gearing.

If gear *17* is retarded, then planet gear *14*, rolling around the internal teeth of gear *17*, will rotate gear *16* $\left(\text{ratio } i = \frac{27}{100}\right)$ and, consequently, the spindle of the moving head with its clamped die.

If, on the other hand, gear *16* is retarded, then planet gear *14* will be the intermediate gear in the transmission with the internal gearing $\left(\text{ratio } i = \frac{22}{60}\right)$ so that gear *17* will rotate relative to gear *16*, and the die on the stationary head spindle will rotate relative to the other die.

After setting up and aligning the relative positions of the dies, lever *31* is shifted back to the position where the eccentric allows spring *24* to disengage shafts *25* and *III*, and cup springs *5* to press friction disks *2* and *3* against gears *16* and *17* again

Mounted on lever *10* is stop *9* which operates a limit switch when the machine is being set up and disconnects it from the power supply.

The double cluster gears are shifted by means of face cam *27* with a closed slot. This cam is rotated by handwheel *29*, brought out on the front wall of the machine.

The four positions of the two cluster gears (Fig. 335) provide for four spindle speeds: 25 5, 39, 63 and 100 rpm These values are engraved on the hub of handwheel *29* and are visible in the slot of indicating member *30*

The hydraulic system provides for moving head approach at a variable speed, penetration of the die into the blank (infeed) and dwell of the moving head against a stop to size the thread

A 1.7-kW electric motor running at 970 rpm drives vane pump *35* (Fig. 334), operating with a maximum pressure of $p = 65$ kg per sq cm and a delivery of $Q = 12$ litres per min The pump draws oil from tank *36*

Back-pressure valve *34* is set to the given pressure Oil passes from valve *34* through fine filter *33* to the central groove of reversing valve *30* Reversing valve *30* is operated by four-way pilot valve *32* which in turn, is controlled by solenoid *31*. When the solenoid is de-energized, oil flows through the

central groove of the reversing valve to flow-control valve *29* which is connected by piping to the ends of the cylinders and to pressure switch *26*.

When the moving head travels to the left, dog *28* releases limit switch *27*. As the dies contact the blank, pressure is built up in the system until pressure switch *26* is operated. The pressure switch closes a motor-type time-delay relay.

Infeed of the moving head is limited by a positive stop. This is followed by thread sizing. The time-delay relay is set up beforehand. At the end of this preset period of time, solenoid *31* is de-energized by the relay, and pilot valve *32* is shifted upward by spring action. As a result, the reversing valve spool is shifted downward and oil from the cylinder drains through the grooves of the reversing valve and back to the tank. At this, the head is withdrawn to the initial position by the action of spring *25*.

Handwheel *23* is mounted on the right end of the stop bar, and differential screw *24* is provided to adjust the position of the head and the length of the stroke to suit the diameter of the thread to be rolled.

The cycle switch is turned to the AUTO position for operation on an automatic cycle. In this case, dog *28* operates limit switch *27* again when the moving head is withdrawn. This energizes solenoid *31* and the cycle is repeated.

The machine will operate on a semiautomatic cycle if the cycle switch is turned to the SEMIAUTO position. In this mode of operation, the moving head stops in the initial position after each cycle. To repeat the cycle it is necessary to press the START push button again.

In setting-up operation with manual controls, solenoid *31* is energized and de-energized only when the START and STOP push buttons are pressed.

The construction provides for the installation of an automatic loading device, enabling the machine to be built into a transfer machine.

CHAPTER 21

GEAR-GRINDING MACHINES

Special precision gear-grinding machines, operating by the generating principle and using an involute cam, are employed in tool production for grinding rotary gear shaving and shaping cutters, and master gears.

Machines are being manufactured in the USSR which grind the teeth of gear-shaping cutters with a worm-type wheel, i.e., a grinding wheel on which a helical thread has been developed.

21-1. Gear-Grinding Machine, Model 5893

The most critical and complex operation in the production of gear-shaping cutters and master gears is the grinding of the tooth profile.

The involute profile of shaping cutter teeth is ground in special semiautomatic machines which operate by the generating principle, the cutter being periodically indexed from tooth to tooth. Only one flank of the tooth is ground in each cycle. The generating motion is imparted to the workpiece. Cutter teeth grinding is based on the meshing of the cutter with a stationary generating rack of which the active wheel surface represents the flank of one tooth.

The well-known principle of constructing an involute curve has been used in the design of the model 5893 gear grinder (Fig. 336). This principle has been realized as shown schematically in Fig 337. The generating line $C'C'$ is stationary while the base circle rotates uniformly about its centre and also travels in a straight line parallel to line $C'C'$ at a velocity equal to the peripheral velocity of a point lying on the base circle.

In the semiautomatic grinder being described, the tangent $A'A'$ to the involute curve (a_0a) is represented by the flat face of the grinding wheel, while the second involute curve (b_0b) is the profile of an accurate cam, coaxial with the cutter being ground and held in constant contact with the roller of a stationary stop by the action of a spring or weight Q. Thus, the profile b_0b of the cam slides along the stationary tangent $B'B'$, contacting it at point B, while the profile a_0a of the cutter tooth slides along tangent $A'A'$, contacting the plane of the grinding wheel (or, more exactly, the trace of this plane) at point A.

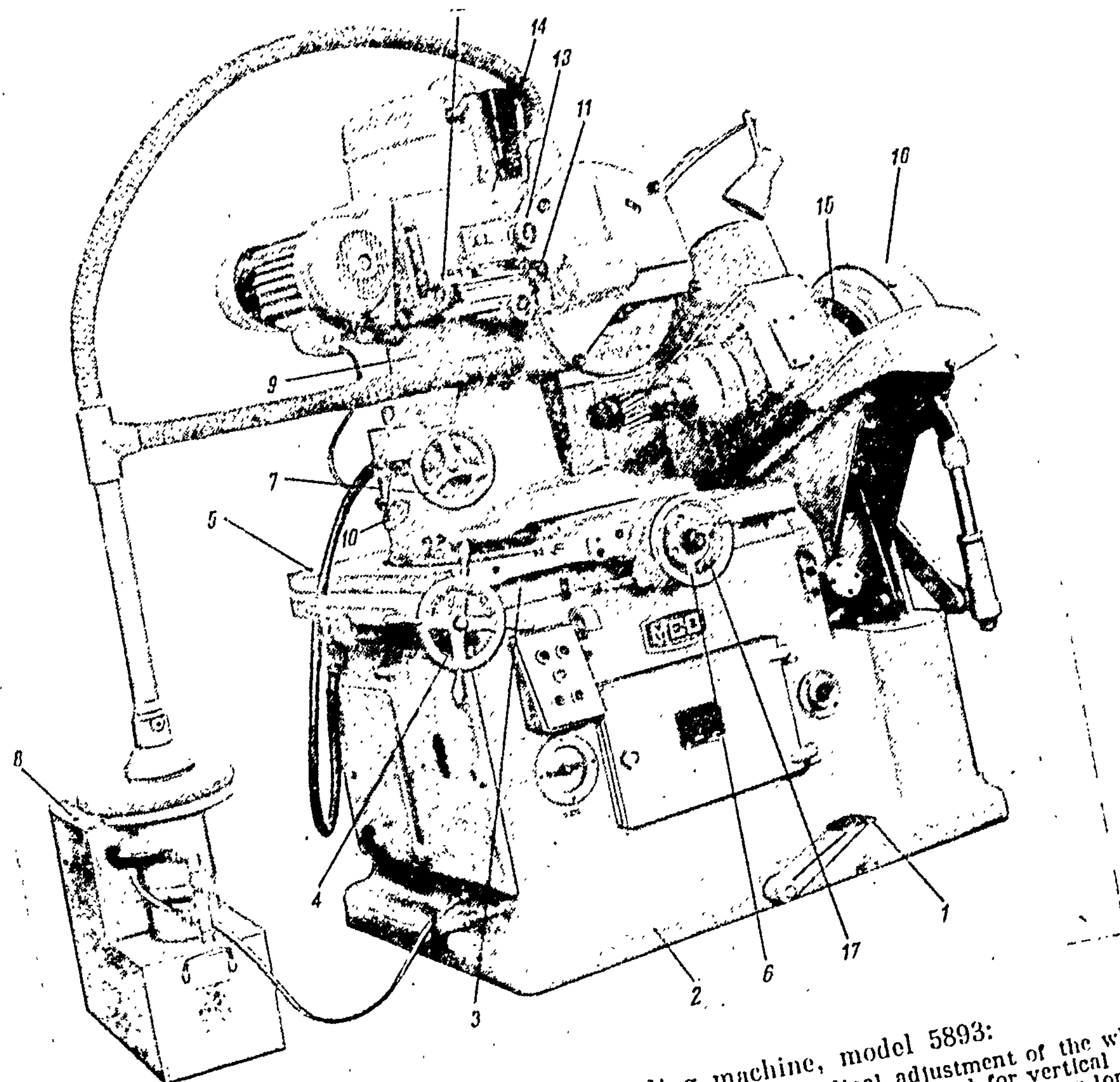


Fig. 336. Semiautomatic gear-grinding machine, model 5893:

1—brake pedal; 2—base; 3—lower table; 4—square shank for longitudinal adjustment of the wheel; 5—upper table; 6—handwheel for crosswise adjustment of the wheel; 7—handwheel for vertical adjustment of the wheel; 8—dust exhauster; 9—column; 10—column swivel control; 11—knob for longitudinal traverse of the wheel dresser; 12—knob for positioning the wheel dresser; 13—knob for crosswise adjustment of the wheel dresser; 14—wheelhead; 15—lever for rotating the workhead by hand; 16—workhead; 17—knob for fine cross feed of the wheel

As the spindle of the grinder rotates with the mounted cutter and cam the whole system travels, under the action of the weight, parallel to gen- erating line $C'C'$. The base circle rolls without slipping along this lin

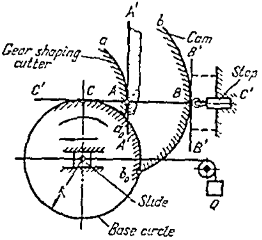


Fig. 337. Principle of the model 5893 gear grinder

The described method of traversing the wheel slide parallel to the generating line is not employed in practice since all the grinding would be carried out by one circle of the wheel, the one described by point A. This would lead to rapid wear of the wheel and a consequently lower accuracy of the ground tooth profile. *Moreover, this arrangement* requires that the base circles of the cam and shaping cutter exactly coincide. Therefore, it would be necessary to have a separate cam for each cutter with a different pitch diameter (the base circle of the cam *is, in a sense, the pitch circle of the* cutter). These drawbacks can be *eliminated by an arrangement in* which the wheel slide, together with *the generating line, is set at an angle α_{set} to the wheel spindle axis* (Fig. 338). In this case, the active surface of the wheel will not be a single circle, as in *the arrangement of Fig. 337,* but an annular surface since the centre of the cutter base circle travels from position O_1 to O_2, along the line O_1O_2, while the cutter tooth profile (or rather its point of contact with the wheel) moves from M_1 to M_2.

A second advantage in setting the slide at various angles α_{set} is that the same cam can be employed for grinding cutters with different pitch diameters. It has been established in practice that these variations in the setting angle, required to enable one cam to accommodate different sizes of cutters, must be within the range from 14° to 30° (or, better still, from 16° to 25°). This restriction is based on the possible interference of the wheel with the next tooth of the cutter at larger values of α_{set}. Besides, the larger the angle α_{set}, the larger the zone M_1M_2 will be. This, however, leads to an excessively large difference between the peripheral speeds at the maximum and minimum diameters of the active zone, causing *nonuniform wear of the* wheel. In practice, the setting angle is selected from the inequality $16° \leqslant \alpha_{set} \leqslant \alpha$, where *$\alpha$ is the pressure angle of the shaping cutter to be ground.*

Gear trains of the grinder (Fig. 339). Rotation is transmitted from electric motor *1* (1 kW, 930 rpm) through V-belt drive *2* with four-step pulleys, *and cone friction* clutch *3* to worm shaft *11*. Rotation is transmitted further to two gear trains: the work head roll and the indexing gear trains.

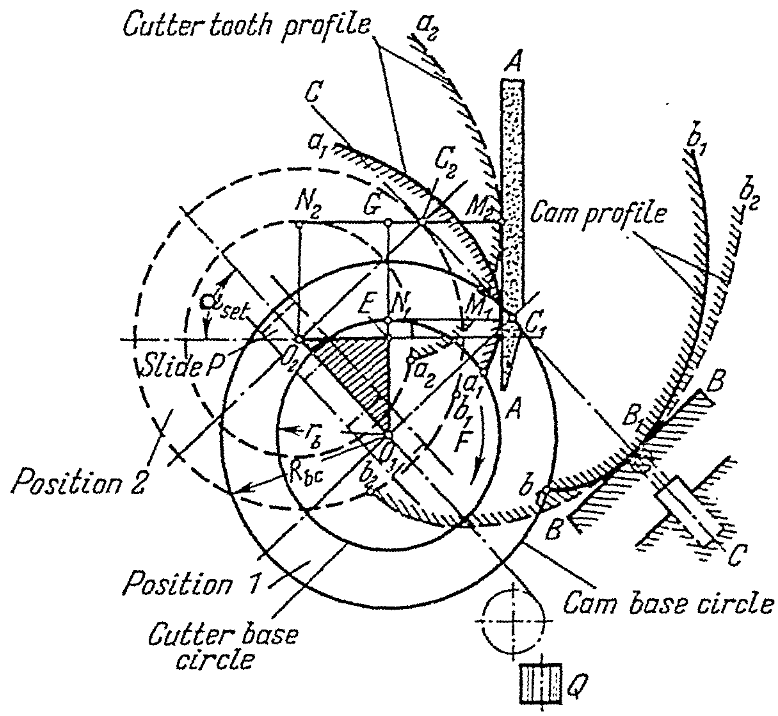


Fig. 338. Slide arrangement at the setting angle

Mounted on the same shaft *15* with worm wheel *13* is crank disk *14* with a diametrical slot milled in one face. Block *17*, adjusted along this slot by screw *16*, carries a crankpin linked through a ball bearing to connecting rod *18*. Upon rotation of worm *12* and worm wheel *13*, connecting rod *18* and the subsequent lever system transmit an oscillating motion about the work spindle axis to the workhead.

The speed and amplitude of workhead motion are determined by the speed of worm shaft *11* and the crankpin radius (position of block *17*) which can be varied in a range from 50 to 110 mm.

In workhead oscillation, involute cam *6*, clamped on the work spindle, bears against the stationary face of adjustable stop *7*, imparting a reciprocating motion to the workhead along the roller ways of slide *8* which are set at an angle to the horizontal.

Weight *9* holds cam *6* in constant contact with the face of stop *7*.

To grind the next tooth, the work is turned by the indexing mechanism mounted in the workhead (Fig. 340). Worm *19* of the indexing mechanism is driven from shaft *11* (Fig. 339) through two pairs of bevel gears, *10* and *4*, and flexible shaft *5*.

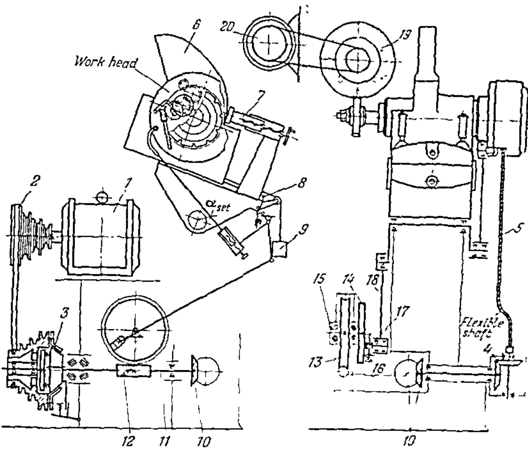


Fig. 339 Gearing diagram of the gear grinder, model 5893

Cam *18* (Fig. 340) is mounted on the same shaft with worm wheel *21* While the tooth profile is being ground, the tooth of locking lever *17* engages a slot of index plate *12*, tying the whole system into an integral unit.

When the tooth has been ground, cam *18* retracts locking lever *17* to release the index plate. Roller *20*, mounted in the end face of worm wheel *21*, enters a slot of Geneva wheel *22*, turning it through one-fourth of a revolution. Through the indexing change gears $\frac{z_1}{z_2} \times \frac{z_3}{z_4}$ and gears *10* and *8*, the roller turns the work spindle through the required angle.

The *workhead* (Fig. 341) has two concentric spindles. The outer spindle *5* is mounted in ball bearings in housing *6*. This spindle carries holder *4* on

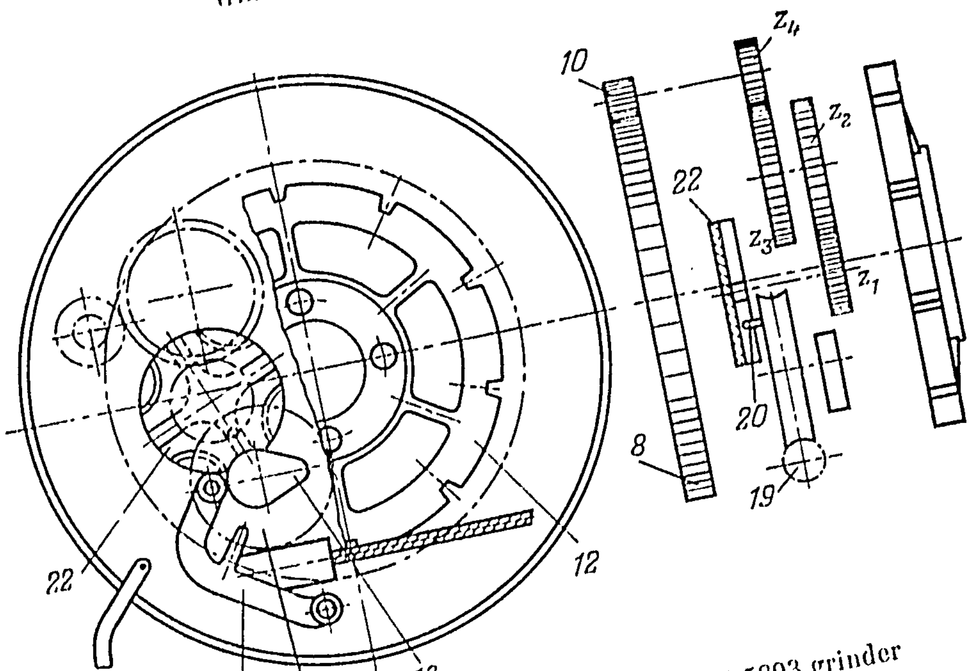


Fig. 340. Indexing mechanism of the model 5893 grinder

which interchangeable involute cams 3 are mounted. Hollow spindle 2 is fitted into the bore of outer spindle 5. Housing 9 of the indexing mechanism is bolted to flange 7 which is secured on the end of outer spindle 5.

Mounted on the inner spindle at one end are central gear 8 and adapter sleeve 13 for seating interchangeable index plates 12.

Work arbor 1 is inserted in the tapered hole at the front end of the inner spindle.

After the grinder is completely set up, arbor 1 is clamped in the spindle by means of draw-bolt 14 and nut 15.

The pivot of locking lever 17 (Figs. 340, 341 and 342), whose tooth seats in the slot of index plate 12, is secured in flange 11 which is bolted to housing 9 of the indexing mechanism. Thus, during the roll motion, spindles 2 and 5 are linked together by locking lever 17. The workhead travels along the roller ways of slide 16. Following each full stroke (back and forth) the shaping cutter is automatically indexed one tooth when the workhead is in the extreme upper position. First cam 18 retracts the tooth of locking lever 17 from the slot of index plate 12, thereby uncoupling spindles 2 and 5. The rotation of Geneva wheel 22 is transmitted through change gears z_1, z_2, z_3 and z_4, gears 10 and 8 to spindle 2. At the end of the indexing motion, the

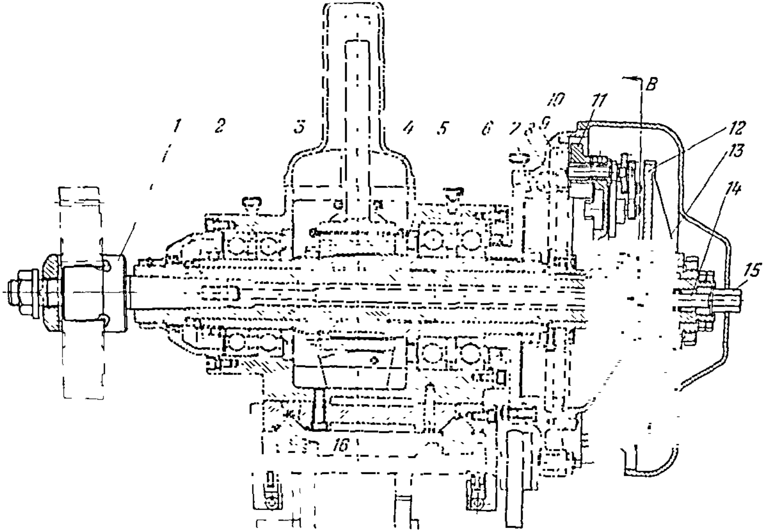


Fig 341 Longitudinal section of the workhead

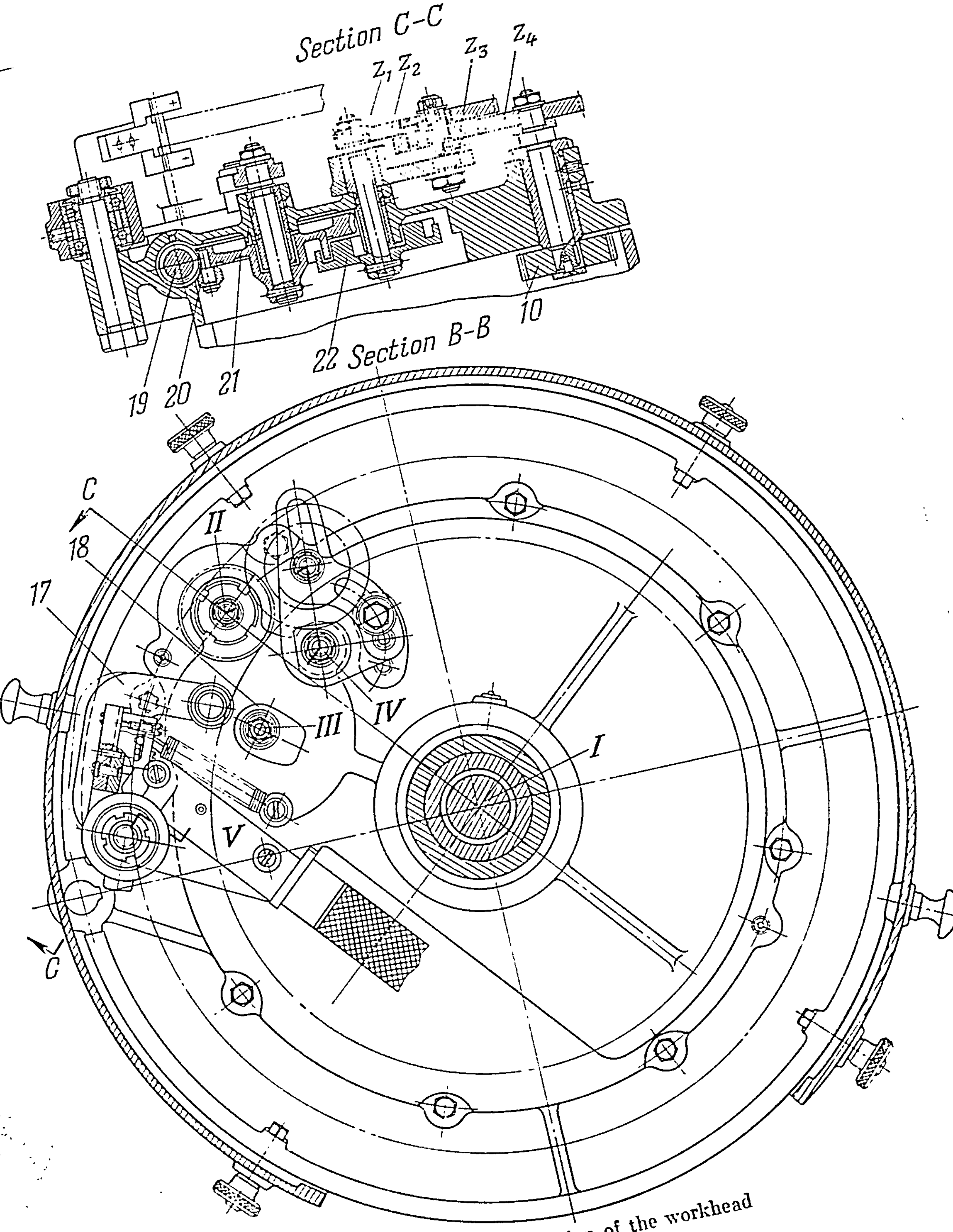


Fig. 342. Cross section of the workhead

tooth of locking lever *17* drops into the next slot of the index plate and the next tooth is ground on the shaping cutter.

The second side of the teeth is ground after the first side has been ground on all the cutters in the lot. For this purpose the wheelhead is swivelled to the same angle in the opposite direction.

The indexing motion of four-slot Geneva wheel *21* through one-fourth of a revolution corresponds to rotation of the shaping cutter being ground through $\frac{1}{z}$ of a revolution, where z is its number of teeth. Thus, the ratio of the indexing change gears can be determined from the equation

$$\frac{1}{4}\times\frac{z_1}{z_2}\times\frac{z_3}{z_4}\times\frac{z_{10}}{z_8}=\frac{1}{z}$$

Hence, since $z_{10} = 33$ and $z_8 = 198$

$$\frac{z_1}{z_2}\times\frac{z_3}{z_4}=\frac{24}{z}$$

The index plate is selected with a number of slots equal to or a multiple of the number of teeth on the cutter to be ground.

The setting angle of the workhead can be determined from the relationship

$$\cos\alpha_{set}=\frac{d_b}{D_{bc}}$$

where d_b = diameter of the base circle of the shaping cutter
D_{bc} = diameter of the base circle of the cam

The workhead can be swivelled by turning handle *13* (Fig. 336) after disconnecting the lever system. To replace the active section of the involute cam upon wear, housing *9* (Fig. 341) is removed from flange *7*. Spindle *5* with involute cam *3* can then be turned to the required position.

The *wheelhead* (Fig. 336) can be adjusted as follows: vertical adjustment to set the height of the wheel to the root diameter of the shaping cutter; crosswise axial adjustment of the wheel (column adjustment); and column adjustment together with the wheelhead along the axis of the shaping cutter being ground.

Grinding wheel *19* (Fig. 339) is powered through a V-belt drive from a separate electric motor *20*. A wheel of large diameter is used to enable the whole face width of the cutter to be ground without making the bottom land excessively curvilinear.

The wheelhead can be swivelled about a vertical axis to set it to the side clearance angle, or to the helix angle in grinding helical shaping cutters.

The wheel swivel angle α_{ws}, required in grinding a spur gear shaping cutter, can be determined from the formula

$$\tan \alpha_{ws} = \tan \alpha_o \sin \alpha_N$$

where α_o = outside angle (relief on top land) of the cutter (usually $\alpha_o = 6°$)
α_N = profile angle of the basic rack form for the sides of the cutter teeth; for standard gearing $\alpha_N = 20°10'14''$.

The gear grinder is furnished with a wheel dressing attachment which can be set at the required angle. This attachment also has a copying device used for modifying the profile of the tooth being ground.

CHAPTER 22
JIG-BORING MACHINES

22-1. General

Jig borers are used to machine holes which must be located with a high degree of accuracy in reference to the datum surfaces of the workpiece (within 0.005, or even 0.001 mm). In addition to all kinds of hole-making operations, these precise machines can be employed for milling flat surfaces, and as a measuring machine for inspection and layout operations.

The measuring systems used to establish precise co-ordinate location can be classified as: mechanical, opticomechanical, optical, opticoelectric and electric.

This chapter deals with the Soviet jig borer, model 2B440, which has an opticomechanical co-ordinate reading and measuring system, using precisely engraved flat glass scales and a viewing screen with a spiral eyepiece micrometer, and with model 2A450 which is an auto-positioning machine incorporating co-ordinate preselection.

22-2. Jig-Boring Machine, Model 2B440

General Data and Brief Specifications

This jig borer (Fig. 343) is intended for machining the holes of jigs, fixtures and various parts requiring accurately located hole centres whose dimensions may be given in either rectangular or polar co-ordinate systems.

Holes up to 40 mm in diameter can be drilled, precision templates can be layed out, and linear and centre-to-centre distances can be measured. The provision of power feed of the table and saddle enables light-duty milling operations to be performed.

The jig borer is furnished with a rotary and inclinable (universal) table employed for the following operations: (a) machining holes whose centres are specified in the polar system of co-ordinates, (b) indexing by means of index plates, and (c) machining inclined holes.

Various accessories facilitate jig borer operation. These include centre-locators, toolholders, etc. A horizontal rotary table is also available.

In design this model is classed with the single-column jig borers having a compound table and a spindle head travelling along the vertical ways of the L-shaped column.

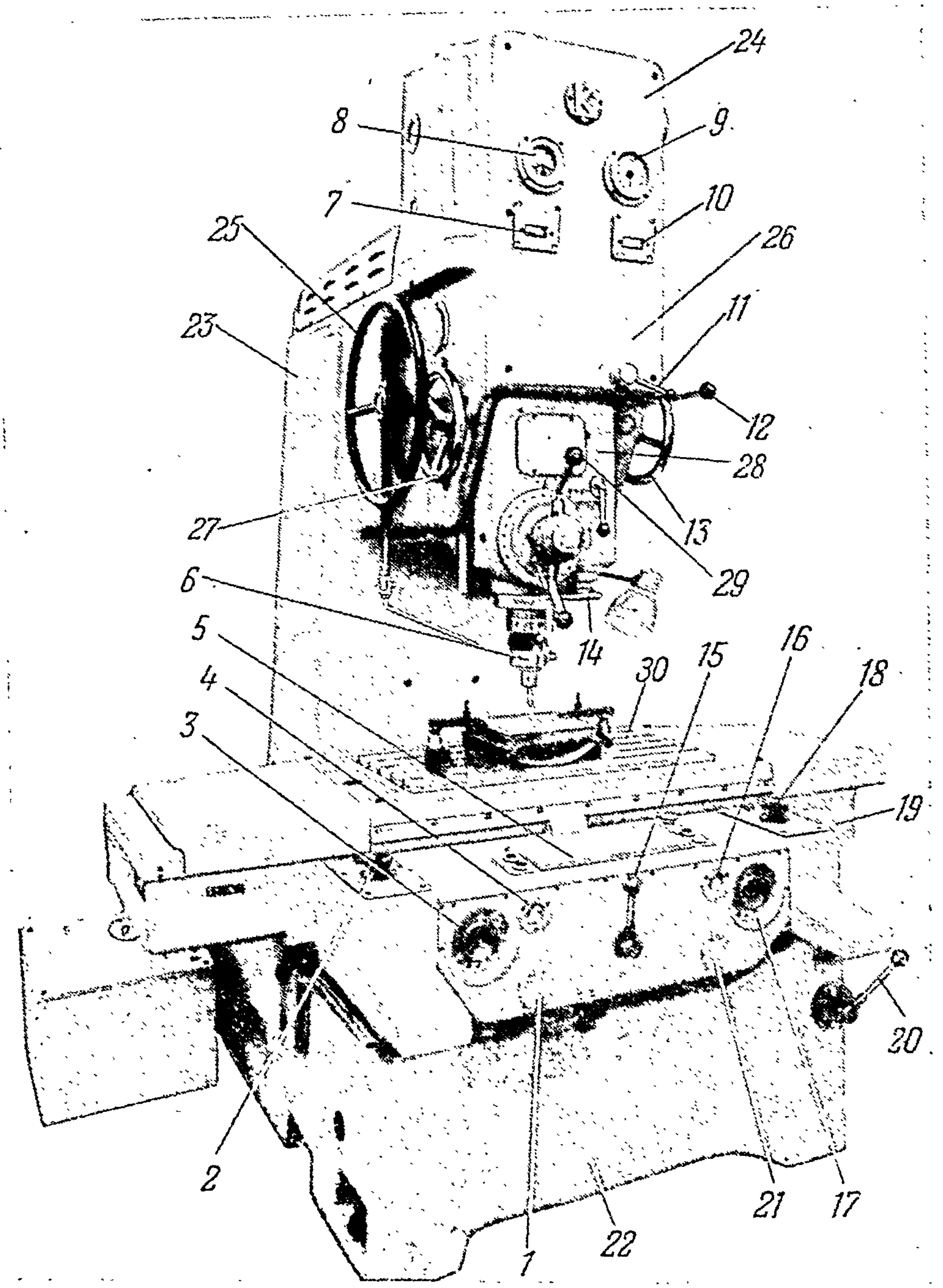


Fig. 343. Jig-boring machine, model 2B440:

1—knob for setting the cross travel scale to zero; *2*—saddle travel speed regulator; *3*—handwheel for hand saddle traverse; *4*—knob of the spiral eyepiece micrometer for the cross travel scale; *5*—screens and push-button controls; *6*—spindle; *7*—speed range indicator; *8*—ammeter; *9*—spindle speed tachometer; *10*—spindle feed indicator; *11*—lever for disengaging and reversing spindle feed; *12*—lever for clamping the spindle head; *13*—handwheel for changing spindle feeds; *14*—handwheel for hand feed of the spindle; *15*—lever for clamping the table; *16*—knob of the spiral eyepiece micrometer for the longitudinal travel scale; *17*—handwheel for hand table traverse; *18*—table travel speed regulator; *19*—saddle; *20*—lever for clamping the saddle; *21*—knob for setting the longitudinal travel scale to zero; *22*—base; *23*—column; *24*—speed gearbox; *25*—handwheel for vertical adjustment of the spindle head; *26*—guide unit; *27*—handwheel for changing spindle speed ranges; *28*—spindle head; *29*—double handle for raising and lowering the spindle quill; *30*—table

This jig borer is equipped with a highly perfected optical measuring system based on the use of flat glass precision scales and a screen with a spiral optical micrometer.

The main drive is powered by a variable-speed d-c electric motor. The motor is regulated by the *G-M* system (generator-motor set according to the Ward-Leonard system) in a range of 4 : 1.

The range of speed provided by the variable-speed motor is expanded by the use of a simple gearbox.

The travel of the spindle head is only for its vertical adjustment.

Quill traverse to provide spindle feeds is accomplished by a linked drive which effects stepless feed variation.

The table and saddle are traversed by a drive based upon a d-c electric motor running at infinitely variable speeds and supplied by a rotary amplifier (*RA*) to which it is connected in series.

The purpose of the table and saddle drive in this machine is not for power positioning motions to make co-ordinate settings, since this type of drive does not provide sufficiently low traverse speeds for this purpose.

The jig borer finds application in tool rooms, as well as in machine and instrument shops for both piece and lot production.

The principal data concerning the model 2B440 jig borer are given in the following specifications:

Brief Specifications

Working surface of the table, mm	800 × 400
Boring capacity, mm	250
Drilling capacity, mm	40
Spindle speed ranges, rpm	50 to 200
	145 to 575
	508 to 2,000
Range of spindle quill feeds, mm per rev	0.03 to 0.16
Range of stepless table (and saddle) feeds, mm per min	16 to 320
Speed of rapid table traverse, mm per min	800
Co-ordinate table setting accuracy, mm	0.001
Electric motors:	
Main drive	
power, kW	2
nominal speed, rpm	700
Table and saddle drives:	
power, kW	0.245
nominal speed, rpm	3,600
Generator drive:	
power, kW	4.5
nominal speed, rpm	1,450

Construction and Gear Trains

Base *22* (Fig. 343) of the jig borer is of box-shaped design, stiffened by heavy internal ribbing. Saddle *19*, travelling in the crosswise direction on the bed ways, has the same type of ways on top, square to the bed ways. Work table *30* travels in the longitudinal direction on the saddle ways.

Both sets of ways are of the antifriction type with steel rollers held in metal retainers. Of each set, one is a V-type and the other a flat way.

The table drive is from d-c variable-speed electric motor *1* (Fig. 344) rated at 0.245 kW and having a nominal speed of 3,600 rpm. The subsequent gear train consists of the double worm gearing *14*, *15*, *16* and *17*, rack pinion *18* and rack *19* secured to the table.

The saddle drive, through the members *6*, *7*, *8*, *9*, *10* and *11*, is similar to the table drive except that the reducing gear of the former is mounted on the saddle and travels with it in reference to rack *11*, fastened to the base.

Handwheels *2*, mounted on the shafts of motors *1* and brought out on the front wall of the control desk (see items *3* and *17* in Fig. 343), are used for fine manual settings of the co-ordinate dimensions. The speed of each motor *1* (Fig. 344) can be regulated in a 50 : 1 range, thereby enabling the table (and saddle) to be rapidly traversed at a speed of 800 mm per min, and surfaces to be milled and positioning motions to be made at speeds from 16 to 320 mm per min.

The table is locked by turning lever *4* (Fig. 344). This screws the threaded end of the shaft out of nut *12*, developing a spreading force between clamping members *3* and *13*.

The saddle is locked in the same way, except that the rotation of lever *23* is transmitted to the screw through the crossed helical gears *21*. In this case the action of the screw and nut *20* actuates clamping members *5* and *22*.

The attainable accuracy of centre-to-centre distances between bored holes, the accuracy of the geometrical features of the holes and their surface finish depend to a considerable extent upon the construction of the spindle unit.

Single-row roller bearings *3* and *4* (Fig. 345) are the radial supports of spindle *5*. The lower bearing is assembled with a slight preload (3 to 6 microns), and the upper with a slight clearance or preload (± 2 microns). Axial loads are carried by ball thrust bearings *2*. Nut *1* at the top end holds the spindle unit together. The spindle is linked to the main drive through spline shaft *1* (Fig. 346) whose upper end is fitted in the spline hole of hollow shaft *54* (Figs. 344 and 346) of the speed gearbox and whose lower end is fitted in the upper spline hole of hollow spindle *5* (Fig. 345). This linkage relieves the spindle of radial loads which could develop due to misalignment of the

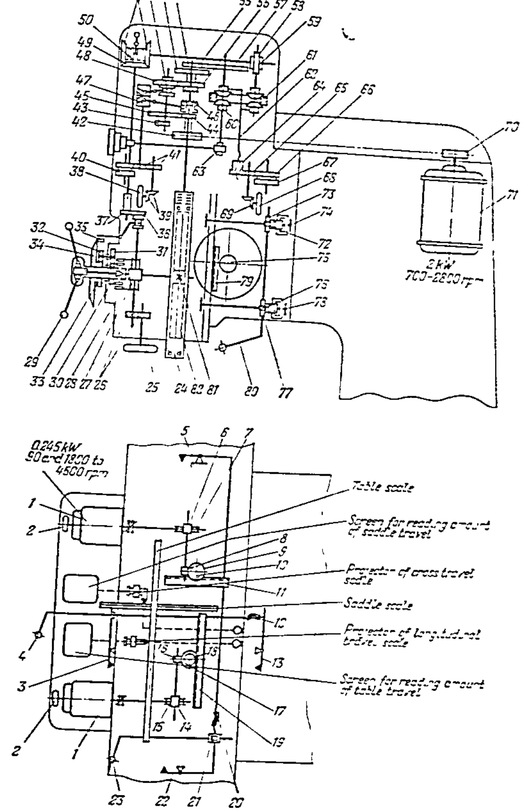


Fig 344 Gearing diagram of the jig borer, model 2B44

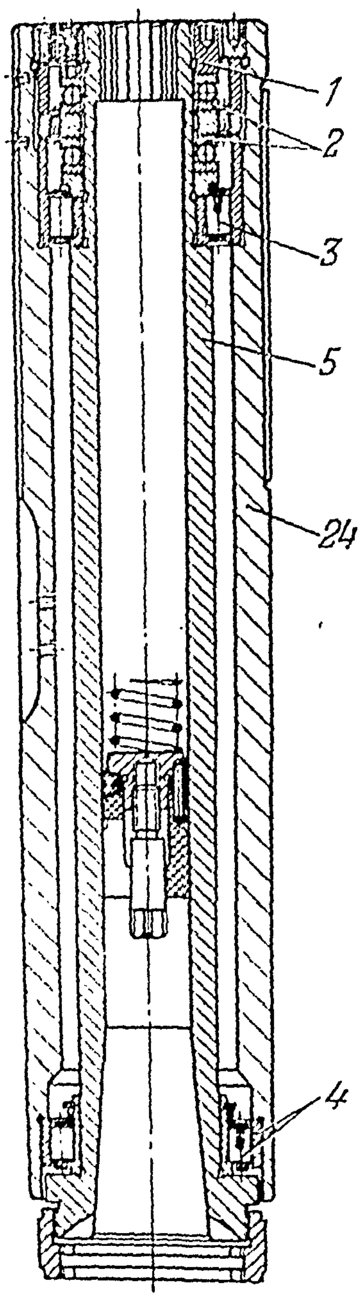


Fig. 345. Spindle unit of the jig borer

spindle and shaft *54* (Fig. 346) since connecting spline shaft *1* mates with these two elements with certain definite clearances between the relatively short mating surfaces. Another advantage is that the spindle can be designed much shorter and its upper end does not protrude from the speed gearbox.

Boring spindle *5* (Fig. 345) is driven by variable-speed d-c electric motor *71* (2 kW, 700 to 2,800 rpm) through V-belts running over pulleys *70* and *42* (Fig. 344), and a three-stage speed gearbox (Figs. 344 and 346).

The first range of spindle speeds is obtained through the following gear train: driven pulley *42* and gears *44*, *45*, *52* and *53*. To obtain the second range, gears *52* and *53* are disengaged and gears *48* and *56* are brought into engagement. Gears *53* and *56* transmit rotation to the spindle through the spline shaft. The third and highest range is obtained when driven pulley *42* is linked directly to the spindle by engaging claw clutch *46* with hollow spline shaft *54* (Fig. 346). In this case, gears *48*, *52*, *53* and *56* do not participate in the drive.

Within each of these three ranges of spindle rotation, the speeds are infinitely variable due to regulation of motor speed in a 4 : 1 range.

The sliding gears and clutch are shifted by levers, one end of which enters one of the slots in control drum *47* (Fig. 344). This control drum is rotated to the required position by turning handwheel *38*, rotation being transmitted through bevel gears *39* and spur gears *41*. On disk *40*, turned simultaneously with drum *47*, figures are engraved indicating the maximum and minimum speeds of each range.

The feed motion is transmitted through the following gear train: gear *55* (Figs. 344 and 346) rotates together with hollow shaft *54* and drives gear *57* on whose shaft the driving cones of adjustable pulley *60* are mounted. Rotation is transmitted to the corresponding driven cones of this stepless speed-changing device through ring *61*.

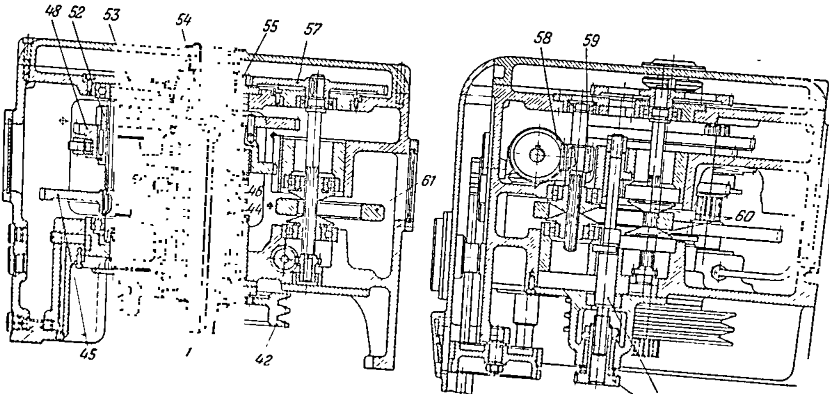


Fig. 316. Speed gearbox of the model 2D440 jig borer

By turning handwheel *68* (Fig. 344), combination nut and gear *64* (Figs. 344 and 346) is rotated through bevel gearing *69* and spur gears *65*. Tie-rod *62* is thus shifted axially and, since it is linked to the upper driving and lower driven cones of the stepless drive, it changes the transmission ratio of the latter. Thus, the driving cones can be brought closer together and the driven cones simultaneously spread apart to increase the speed of worm *59*, or the driving cones can be spread and the driven brought together to reduce the speed of worm *59*. This arrangement provides for infinitely variable feeds per spindle revolution.

The rate of feed is indicated on drum *67* (Fig. 344) which is also rotated through gears *65* and *66* when handwheel *68* is turned.

On the shaft of worm wheel *58* (Figs. 344 and 346), driven by worm *59*, two bevel gears *51* are freely mounted (Fig. 344). These bevel gears mesh constantly with bevel gear *49*. The engagement of clutch *50* to one of gears *51* provides for either right- or left-hand rotation of worm *28*. Thus, the spindle can be fed either up or down.

Worm wheel *27* is freely mounted on the shaft of rack pinion *81* which is in constant mesh with rack *82* of spindle quill *24* (Figs. 344 and 345). Worm wheel *27* is linked to the shaft of pinion *81* by means of a clutch mounted in the worm wheel and engaged by shifting double lever *29* fitted on the shaft of pinion *81*.

If the clutch is disengaged, rack pinion *81* can be rotated directly from the double lever to rapidly raise or lower spindle quill *24*.

Fine hand feed is effected by turning handwheel *25* whose rotation is transmitted through gears *26*.

Working power feed is automatically disengaged, when the preset depth of machining is reached, by dog *35* which can be adjusted on dial *34*. This dog shifts gear *36* out of mesh with gear *37*.

Disengagement occurs when the zero graduation of the dial coincides with the zero graduation of the vernier. This device operates with a linear accuracy within 0.2 or 0.3 mm.

A reducing gear train consisting of gears *30*, *31*, *32* and *33* is provided between dial *34* and the shaft of rack pinion *81*. Consequently, the dial makes only one revolution for the whole length of spindle quill travel.

The set-up spindle speed is indicated on a tachometer driven through spur gears *55* and *57* and crossed helical gears *63*.

A gear-type lubrication pump is driven by spur gears *43* from the intermediate shaft.

The spindle head is adjusted manually along the vertical ways by turning handwheel *25* (Fig. 343) whose rotation is transmitted through worm gearing and bevel gearing to rack pinion *75* (Fig. 344) which meshes with rack *79* secured to the spindle head housing.

Spindle head *28* (Fig. 343) is locked on the V-ways by clamps which are actuated through tie-rods and screws *74* and *78* (Fig. 344), gears *72* and *76*, and combination gears and nuts *73* and *77*, when lever *80* is shifted.

Optical System

Table travel is measured in making co-ordinate settings by means of precision glass scales and an optical system enabling greatly magnified images of the scale graduations and figures, as well as a spiral micrometer reticle, to be projected on easily read screens.

The jig borer actually has two such optical systems: one for reading the amount of longitudinal travel of the table, and the other for cross travel of the saddle.

The table scale is a moving element of the longitudinal system (see Fig. 344) being secured to the table and travelling with it in respect to the rest of the optical system.

The optical system is the moving element of the cross travel system and travels crosswise in respect to the stationary saddle scale secured to the base.

The two optical systems are identical except that prisms and mirrors are included in the cross travel system to change the path of the light beam and enable the eyepiece to be more conveniently located.

Only the longitudinal optical system for table travel is considered in the following (Fig. 347*a*). The beam passes from the electric lamp of illuminator *1* through collecting and condensing lenses *2* and *3* and is condensed in the plane of the graduations of scale *5*. Glass strip *4* has no graduations; its purpose is to protect the scale surface with graduations against dust.

The beam of light passes through glass scale *5*, objective *6* and optical flat *7* projecting a fivefold magnified image of the scale graduations and figures onto the plane of the reticle on which the spiral eyepiece micrometer *8* has been engraved.

After passing further through projection eyepiece *9* and cover glass *10*, the image of the scale graduations is reflected from flat mirrors *11* and *13* and projected onto screen *12* with a magnification of 60×. The fractional part of the dimension is read by the aid of the spiral micrometer which is also projected onto the screen (Fig. 347*b*). Readings to 0.001 mm are made directly.

The optical system incorporates a correction device which compensates for errors in graduating the glass scales, introduces corrections into the reading on the scale and eliminates accumulated error.

Correction is effected by turning optical flat *7* (Fig. 347*a*) about a horizontal axis; this shifts the scale image on the screen by the required amount.

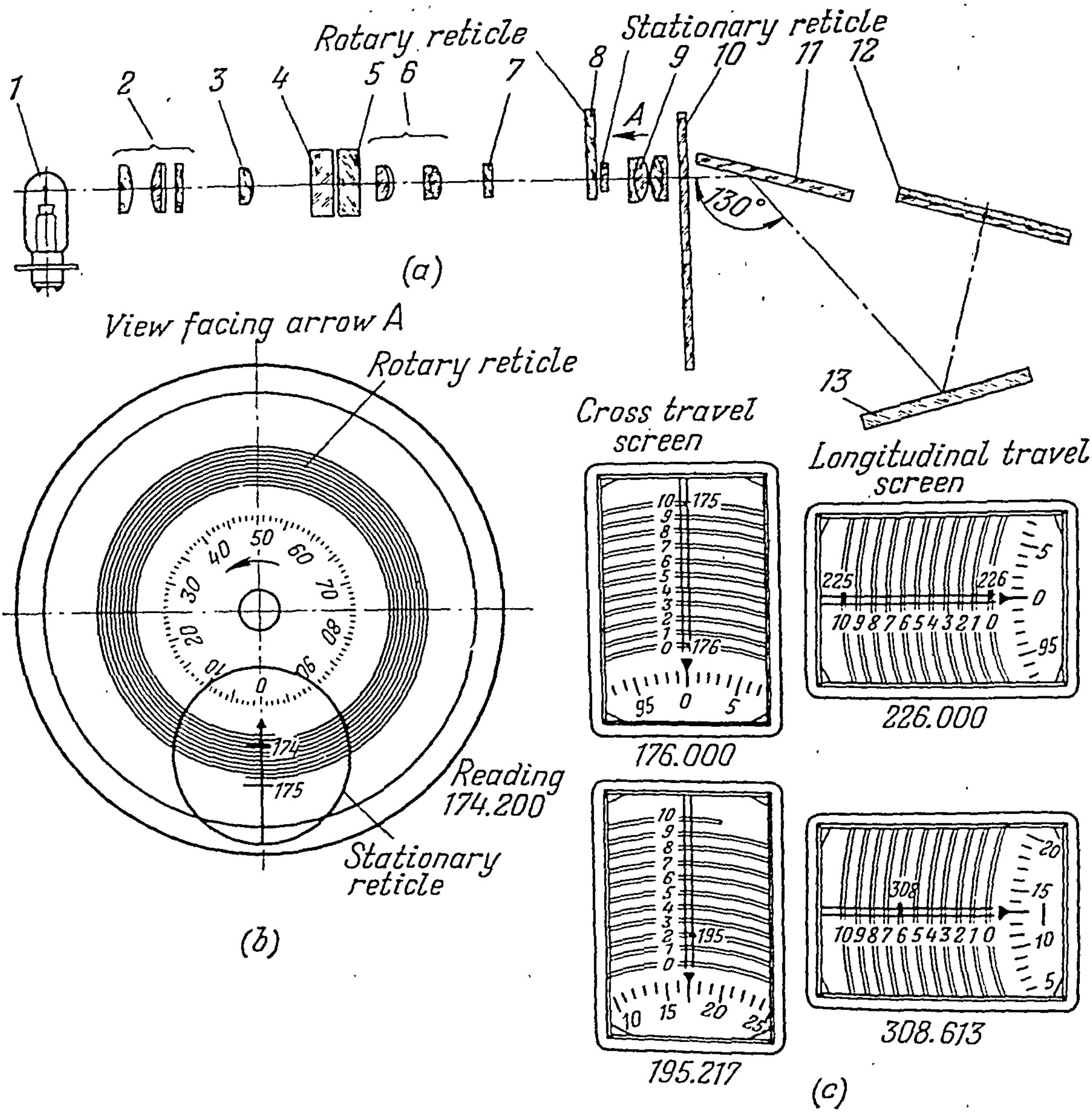


Fig. 347. Optical system of the model 2B440 jig borer:
(a) light path diagram; (b) rotary and stationary reticles of the spiral eyepiece micrometer; (c) co-ordinate readings on the screens

The optical flat, mounted in the path of the light beam, is tilted by means of a lever system actuated by a correction bar mounted on the table (or base). Both accumulated and local errors in the graduations of the glass scale can be compensated for by the correction bar. The bar is swivelled to the required

angle to correct accumulated errors; the active surface of the bar is made with an appropriately curved profile to correct local errors.

To shift the image of a scale graduation by 0.001 mm on the screen, the lever must be raised or lowered by 0.2 mm on the correction bar.

Spiral eyepiece micrometer *8* has two reticles, one rotary and the other stationary (Fig. 347*b*).

Engraved on the rotary reticle is a double *Archimedean spiral whose pitch* is equal to 0.5 mm. This corresponds to 0.1 mm of scale *5* (Fig. 347*a*) whose image is projected onto the plane of the reticle with a fivefold magnification.

A circular scale in the centre of the rotary reticle (Fig. 347*b*) has 100 graduations, each fifth graduation being numbered. The rotary reticle can be rotated in reference to the stationary one on which an index line and arrow head are engraved. The index line is divided into ten equal divisions (Fig. 347*c*) of a size equal to the pitch of the spiral engraved on the rotary reticle.

The index line graduations are numbered and, when the circular scale is set to zero opposite the arrow, these graduations are in the middle of the corresponding turn of the spiral. In each full revolution of the rotary reticle, the spiral is shifted in reference to the stationary index line by one pitch, i.e., 0.1 mm. Linear shift of the spiral by one pitch corresponds to one full revolution of the circular scale. Therefore, its divisions are equal to 0.1 mm $\times \frac{1}{100} = 0.001$ mm or one micron. This so-called micron scale is used to read off hundredths and thousandths of a millimetre.

When the circular scale graduations representing hundredths and thousandths are turned to the index line, the spiral is shifted by the same amount in reference to the index line graduations.

As the table (or saddle) is traversed, the image of the numbered millimetre graduations of the glass scale moves along the index line.

The rotary reticle (Fig. 347*b*) is arranged in a mount which is rotated through a system of gearing by turning knob *16* (Fig. 343).

It proves convenient in reading off the co-ordinate dimensions to assume that the initial position is one in which the centre *of the datum hole in the* workpiece clamped on the work table is made to coincide with the spindle axis. *This is done in the following* order:

(1) the zero graduation of the circular scale is set opposite the index arrow by turning knob *16*,

(2) by turning knob *21* the image of the nearest *millimetre graduation* is set to the middle of the spiral turn designated as zero (the view on the screen will be as in *Fig. 347c*).

(3) *the same setting is made* on the cross travel screen by first turning knob *4* (Fig. 343) and then knob *1*:

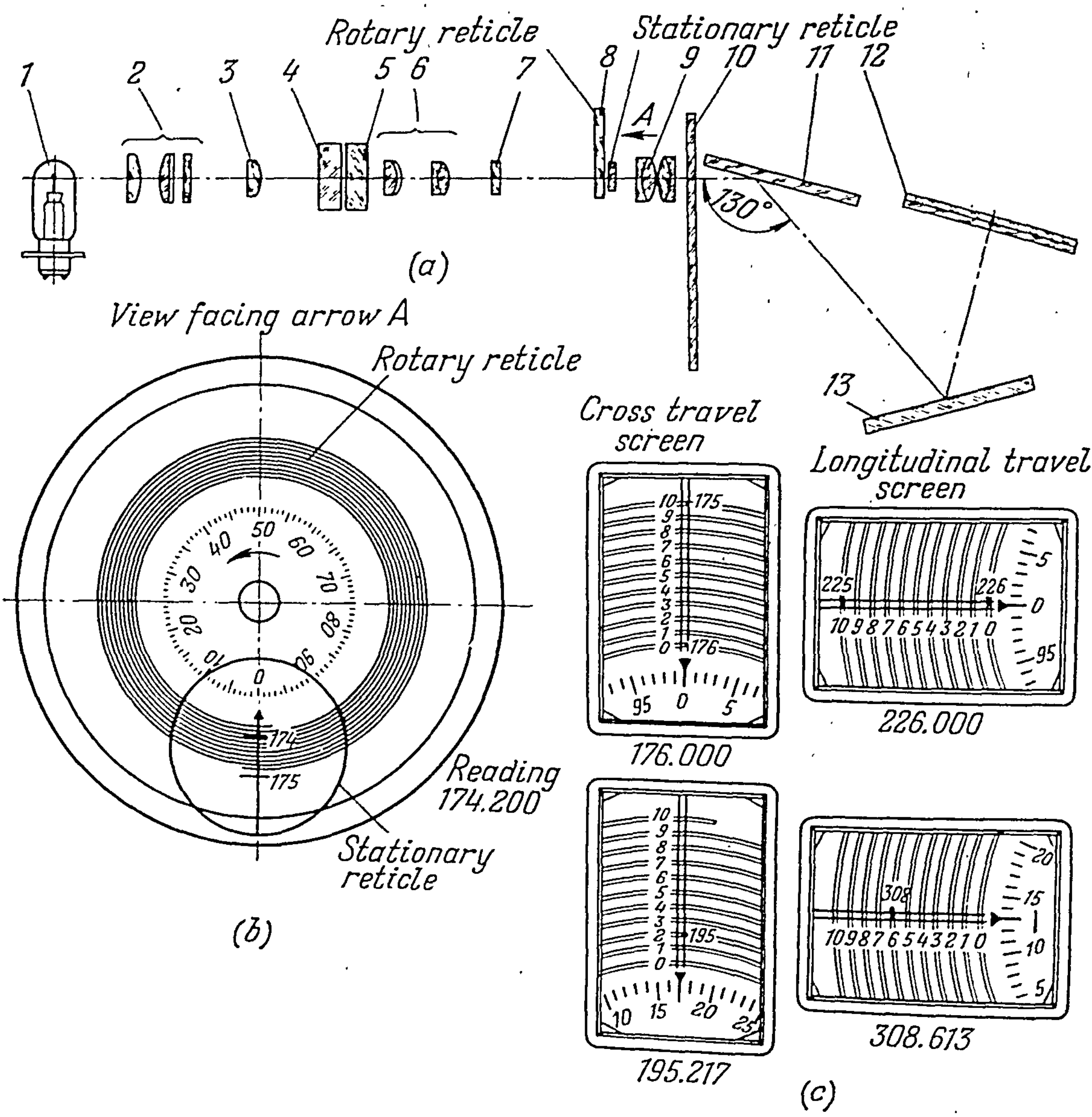


Fig. 347. Optical system of the model 2B440 jig borer:
(a) light path diagram; (b) rotary and stationary reticles of the spiral eyepiece micrometer; (c) co-ordinate readings on the screens

The optical flat, mounted in the path of the light beam, is tilted by means of a lever system actuated by a correction bar mounted on the table (or base). Both accumulated and local errors in the graduations of the glass scale can be compensated for by the correction bar. The bar is swivelled to the required

angle to correct accumulated errors; the active surface of the bar is made with an appropriately curved profile to correct local errors.

To shift the image of a scale graduation by 0.001 mm on the screen, the lever must be raised or lowered by 0.2 mm on the correction bar.

Spiral eyepiece micrometer 8 has two reticles, one rotary and the other stationary (Fig. 347*b*).

Engraved on the rotary reticle is a *double Archimedean spiral* whose pitch is equal to 0.5 mm. This corresponds to 0.1 mm of scale *5* (Fig. 347*a*) whose image is projected onto the plane of the reticle with a fivefold magnification.

A circular scale in the centre of the rotary reticle (Fig. 347*b*) has 100 graduations, each fifth graduation being numbered. The rotary reticle can be rotated in reference to the stationary one on which an index line and arrow head are engraved. The index line is divided into ten equal divisions (Fig. 347*c*) of a size equal to the pitch of the spiral engraved on the rotary reticle.

The index line graduations are numbered and, when the circular scale is set to zero opposite the arrow, these graduations are in the middle of the corresponding turn of the spiral. In each full revolution of the rotary reticle, the spiral is shifted in reference to the stationary index line by one pitch, i.e., 0.1 mm. Linear shift of the spiral by one pitch corresponds to one full revolution of the circular scale. Therefore, its divisions are equal to $0.1 \text{ mm} \times \times \frac{1}{100} = 0.001$ mm or one micron. This so-called micron scale is used to read off hundredths and thousandths of a millimetre.

When the circular scale graduations *representing hundredths and thousandths* are turned to the index line, the spiral is shifted by the same amount in reference to the index line graduations.

As the table (or saddle) is traversed, the image of the numbered millimetre graduations of the glass scale moves along the index line.

The rotary reticle (Fig. 347*b*) is arranged in a mount which is rotated through a system of gearing by turning knob *16* (Fig. 343).

It proves convenient in reading off the co-ordinate dimensions to assume that the initial position is one in which the centre of the datum hole in the workpiece clamped on the work table is made to coincide with the spindle axis. This is done in the following order.

(1) the zero graduation of the circular scale is set opposite the index arrow by turning knob *16*;

(2) by turning knob *21* the image of the nearest millimetre graduation is set to the middle of the spiral turn designated as zero (the view on the screen will be as in Fig. 347*c*);

(3) the same setting is made on the cross travel screen by first turning knob *4* (Fig. 343) and then knob *1*;

(4) the co-ordinate settings for longitudinal and cross travel are determined by adding or subtracting the given dimensions (depending upon the direction of travel) to or from the initial readings;

(5) the hundredths and thousandths in the fractional part of the dimension are set up on the circular scale by turning knobs *16* and *4*;

(6) the table (or saddle) is traversed to a position where the numbered millimetre graduation of glass scale *5* (Fig. 347*a*) coincides with the middle of the spiral turn corresponding to the number of tenths in the fractional part of the dimension being set up.

A view of the screens with definite settings is given in Fig. 347*c*.

Thus, the complete dimension consists of whole millimetres, tenths, and hundredths and thousandths of a millimetre which are represented by the numbered graduations of the glass scale, numbered turns of the spiral and the reading on the circular scale, respectively.

Electric Circuit

The electric circuit of the jig borer (Fig. 348) includes the electric drives for the spindle, table, saddle and coolant pump; lighting facilities for the optical system; interlocking and protection of certain units under various operating conditions.

Boring spindle rotation, and traverse of the table and saddle are powered by d-c electric motors; and induction motor drives the coolant pump.

The spindle drive motor is supplied from a generator-motor set, the table and saddle motors are supplied from a rotary amplifier.

The machine circuit is connected to the power supply by turning the rotary main line switch *MLS*. At this, lamps *1SL* and *2SL* illuminate the dial of the speed gearbox.

A voltage is applied over the field windings of motor *M* and generator *G* by the selenium rectifier *SR*, and over the field windings of motors *TM* and *SM* from generator *G*.

The *generator and rotary amplifier RA* are switched on in the following way. Upon pressing the GENERATOR push button *2PB*, contactor *1C* is closed. This starts generator drive motor M_1, rotary amplifier motor M_4 and coolant pump motor M_2 (if plug *1P* is inserted).

Spindle drive. The electric circuit is designed for switching on spindle rotation, switching it off with or without braking, stepless variation of spindle speeds, and slow rotation at the "creeping" speed.

First stage in starting the spindle. When the SPINDLE START push button *4PB* is pressed, contactor *3C* connects spindle drive motor *M* to the generator through braking and starting resistor *1RB*.

Second stage in starting the spindle. Time-delay relay *1TDR* is energized at the same time that push button *4PB* is pressed and, after a definite interval, it closes contactor *4C* which cuts out the time-delay relay and shunts over resistor *1RB*.

Slow spindle rotation. Pressing the SPINDLE SLOW push button *8PB* starts slow rotation of the motor (40 to 60 rpm) to obtain the "creeping" spindle speed used in aligning the work by means of a centre locator. In this case, relay *4AR* is closed so that the full voltage is applied over field winding *FWM* while field winding *FWG* of the generator is connected through series resistor *1RS*. The series winding *SWG* of the generator is shunted to eliminate variation in speed.

Changing the spindle speed. The motor speed is changed in the range from the nominal to maximum values (700 to 2,800 rpm) with the aid of a shunt regulator. When either the FASTER *5PB* or SLOWER *6PB* push button is pressed, a-c commutator motor M_3 is switched on in either one or the other direction. This motor moves the slide of shunt regulator *SHR* adding or removing resistance in the circuit of the field winding *FWM* of the spindle drive motor.

Limit switches LS_8 and LS_9 restrict the angle of rotation of the regulator in the extreme positions by switching off motor M_3.

Spindle braking. Motor *M* can be stopped with or without braking by pressing push button *3PB*. If this button is pressed down as far as it goes, contactor *5C* is closed and contactors *3C* and *4C* are opened simultaneously.

The contacts of *3C* disconnect the armature of motor *M* from the power supply while that of contactor *5C* connects the armature to resistor *1RB* (operating as a braking resistor in this case). The full voltage is applied to the field winding *FWM*. Intensive dynamic braking occurs, which continues as long as push button *3PB* is held down or until the armature stops running. Motor *M* is stopped without braking by pressing push button *3PB* part way down. In this case, contactors *3C* and *4C* are opened, but contactor *5C* is not.

Electric Drives of the Table and Saddle

The electric circuit of the jig grinder provides for positioning traverse to set the co-ordinate dimensions, working feed of the table and saddle for milling operations, and their rapid traverse motions. The table and saddle can only be traversed separately.

Slow ("creeping") traverse of the table and saddle. The table or saddle drive motor (*TM* or *SM*) is started by turning the corresponding speed regulator (*1SPR* or *2SPR*) in one or the other direction. This closes magnetic starters *1MSF* and *1MSR* or *2MSF* and *2MSR*. The difference betwe[illegible]

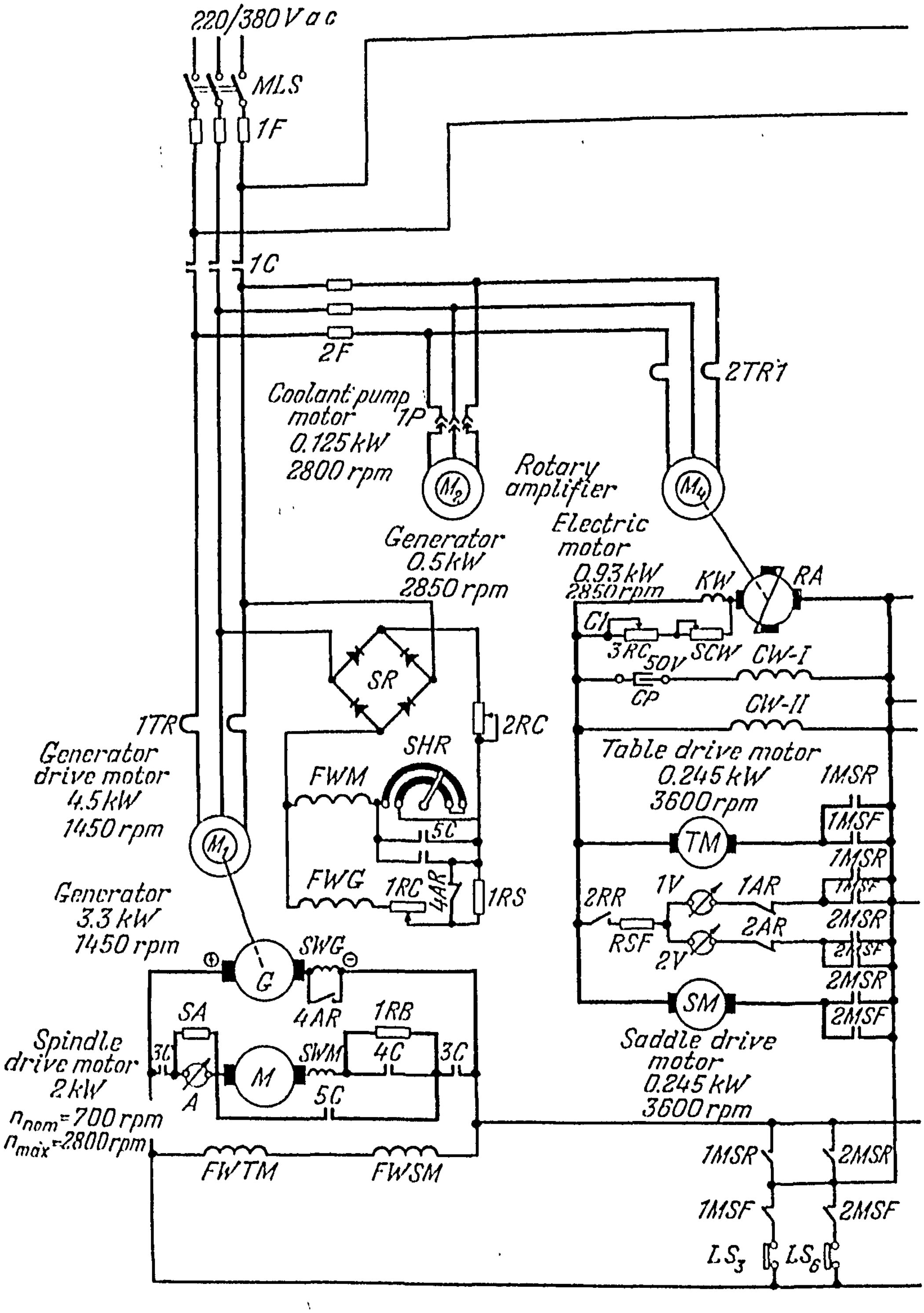
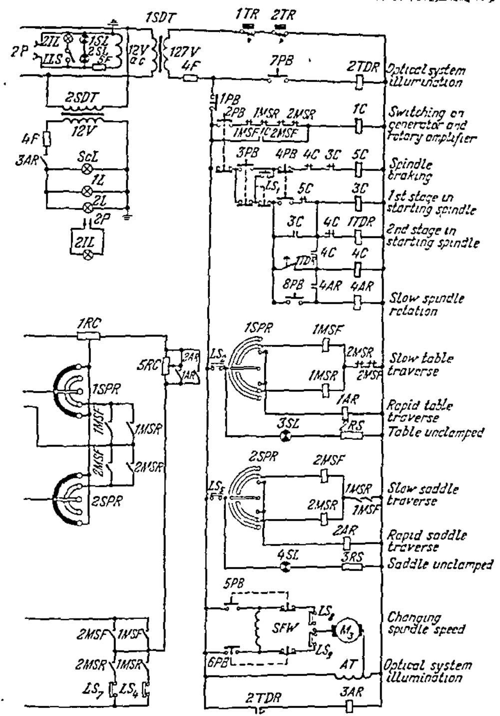


Fig. 348. Elementary diagram of the electric

Electric motors: *M*—spindle drive; *SM*—saddle drive; *TM*—table drive; M_1—generator drive;
G—generator. Contactors: *1C*—for motors M_1, M_2 and M_4; *3C* and *4C*—for starting motor *M*
1MSR—control of motor *TM* for travel to LEFT; *2MSF*—control of motor *SM* for travel AWAY;
for motor *TM*; *2AR*—for motor *SM*; *3AR*—auxiliary relay for switching on optical system illumination;
2TDR—for optical system illumination; *1TR* and *2TR*—thermal relays protecting motors. Push but
braking, starting, accelerating and decelerating motor *M*; *7PB*—illuminating optical system and set
spindle travel; LS_3 and LS_4—table travel to right and left; LS_6 and LS_7—saddle travel away and to
of table and saddle; other switches: *MLS*—main line switch; *LLS*—local lighting switch. *1F*, *2F*, *3F*
of motor *M*; *FWG*, *FWM*, *FWTM* and *FWSM*—field windings of the generator and motors *M*, *TM*
regulator of motor *M*; *CP*—stabilizing capacitor; *1SDT* and *2SDT*—step-down transformers; *1SPR*
saddle speeds); *CW-I* and *CW-II*—control windings of rotary amplifier *RA*; *SR*—selenium rectifier;
RA; *SCW*—shunt of the compensating winding of *RA*. Lamps: *1SL* and *2SL*—signal lamps; *1IL* and
2RS, *3RS* and



circuit used in the model 2B440 jig borer:

M_4—coolant pump drive, M_5—for adjusting speed regulator slide M_6—rotary amplifier drive. in stages: $5C$—for braking motor M, $1MSF$—control of motor TM for travel to RIGHT, $2MSR$—control of motor SM for travel TOWARD Auxiliary relays for forcing motor speeds $1AR$— $4AR$—relay for slow spindle rotation Time-delay relays. $1TDR$—for starting motor M in stages tons: $1PB$ and $2PB$—for stopping and starting motor M_1, $3PB$, $4PB$, $5PB$ and $6PB$—stopping and [illegible] limit switches LS_1— [illegible], and LS_6—clamping

reference voltage supplied by the speed regulator *1SPR* or *2SPR* and the voltage of rotary amplifier *RA* is applied to the control winding *CW-II* of the rotary amplifier (negative voltage feedback).

Negative voltage feedback serves to reduce the inertia in the rotary amplifier and to flatten the characteristic curve of the motor. The flat characteristic required to provide the given range of speeds is obtained by selecting the necessary degree of overcompensation of the rotary amplifier using the calibrating resistance *3RC* which is connected in series with the shunt *SCW* of the compensating winding.

As the speed regulators *1SPR* and *2SPR* are turned, more or less voltage is applied to the control winding *CW-II* of the rotary amplifier. This varies the motor speed in a stepless range from 90 to 1,800 rpm and thus the required milling feeds and positioning traverse of the table or saddle are obtained. The motor speeds can be varied in a range of 1 : 40 below and 1 : 1.25 above the nominal speed.

The polarity of the voltage applied to regulators *1SPR* and *2SPR* is changed and the drive motors are reversed by the magnetic starters *1MSF* and *2MSF* or *1MSR* and *2MSR*.

Rapid table and saddle traverse (800 mm per min). This motion is accomplished at the maximum speed of motors *TM* and *SM* (4,500 rpm) and corresponds to the extreme positions of regulators *1SPR* and *2SPR* in which relays *1AR* and *2AR* are closed, shunting over resistor *5RS* in the circuit of the reference signal. The voltage of rotary amplifier *RA* is applied over its control winding *CW-I* in series with capacitor *CP* which serves to eliminate fluctuations and to smooth out transients.

When the voltage drops, winding *CW-I* magnetizes the rotary amplifier and demagnetizes it when the voltage increases.

Table and saddle speeds are indicated by voltmeters *1V* and *2V* having scales graduated directly in mm per min. The voltmeters are switched in by push button *7PB*. Clamping of the table and saddle is controlled by limit switches LS_2 and LS_5, and signal lamps *1SL* and *2SL*. The table or saddle can be traversed only after it is released. The table or saddle is restricted in its extreme positions by limit switches LS_3 and LS_4 or LS_6 and LS_7.

Illumination of the optical system. The SCALE LIGHT push button *7PB* also illuminates the optical system. When the button is pressed, the coil of time-delay relay *2TDR* is energized and it closes relay *3AR*. The latter switches on the lamps *1L*, *2L* and *ScL* for illuminating the optical system and scales. The lamps remain on as long as the push button is held down, plus the time the relay is set for.

All the motors are stopped if push button *1PB* is pressed; it de-energizes the whole control circuit.

Recently, the generator-motor system in the design of the main drive was replaced by a magnetic amplifier. This substitution led to a reduction

in noise, easier maintenance, a saving of power and other advantages. Certain other changes were also made to simplify the electric circuit and improve its operation.

22-3. Jig-Boring Machine, Model 2A450

The principal distinguishing feature of the model 2A450 jig borer is that the co-ordinate settings for the next hole can be made while a hole is being machined. When the hole is finished a push button *is depressed to automatically* position the table and saddle to the new co-ordinate setting. This is known as auto-positioning, or co-ordinate preselection, and it substantially reduces the nonproductive handling time.

The jig borer has an optical co-ordinate reading and measuring system; the numbered graduations of precise glass scales are projected onto a stationary reticle by the aid of which the complete decimal part of the co-ordinate setting can be read off directly from a single place.

Holes up to 40 mm in diameter can be drilled, precise templates can be layed out, and linear and between-centres distances can be measured. The jig borer can also be used for light-duty milling operations.

The machine can be *efficiently* employed in tool rooms, and machine and instrument shops, both for piece and lot production runs.

Gear Trains (Fig. 350)

For location in a rectangular co-ordinate system the work is traversed in the following way: the work is clamped on the table (see Fig. 349) and travels with it in the longitudinal direction along the saddle ways. The saddle together with the table and workpiece travels in the transverse direction on the base ways.

Table traverse is *powered* by variable-speed d-c electric motor *12* (0.245 kW, 3,600 rpm) *through double worm gearing 8, 9, 11* and *13*, rack pinion *10* and rack *11* secured on the table.

The saddle drive, through members *12, 15, 16, 17, 18, 19* and *20*, is similar to the table drive except that the reducing gear of the former is mounted on the saddle and travels with it in reference to rack *20* fastened to the base.

Handwheels *2*, brought out on the front wall of the control desk, are used for fine manual settings of the co-ordinate dimensions.

The speed of each motor *12* can be regulated in a wide range, enabling the table (and saddle) to be *rapidly traversed at a speed* of 1,200 mm per min, surfaces to be milled at feeds from 30 to 200 mm per min, and auto-positioning to the preselected co-ordinates to be *carried out at a slow ("creeping")* speed.

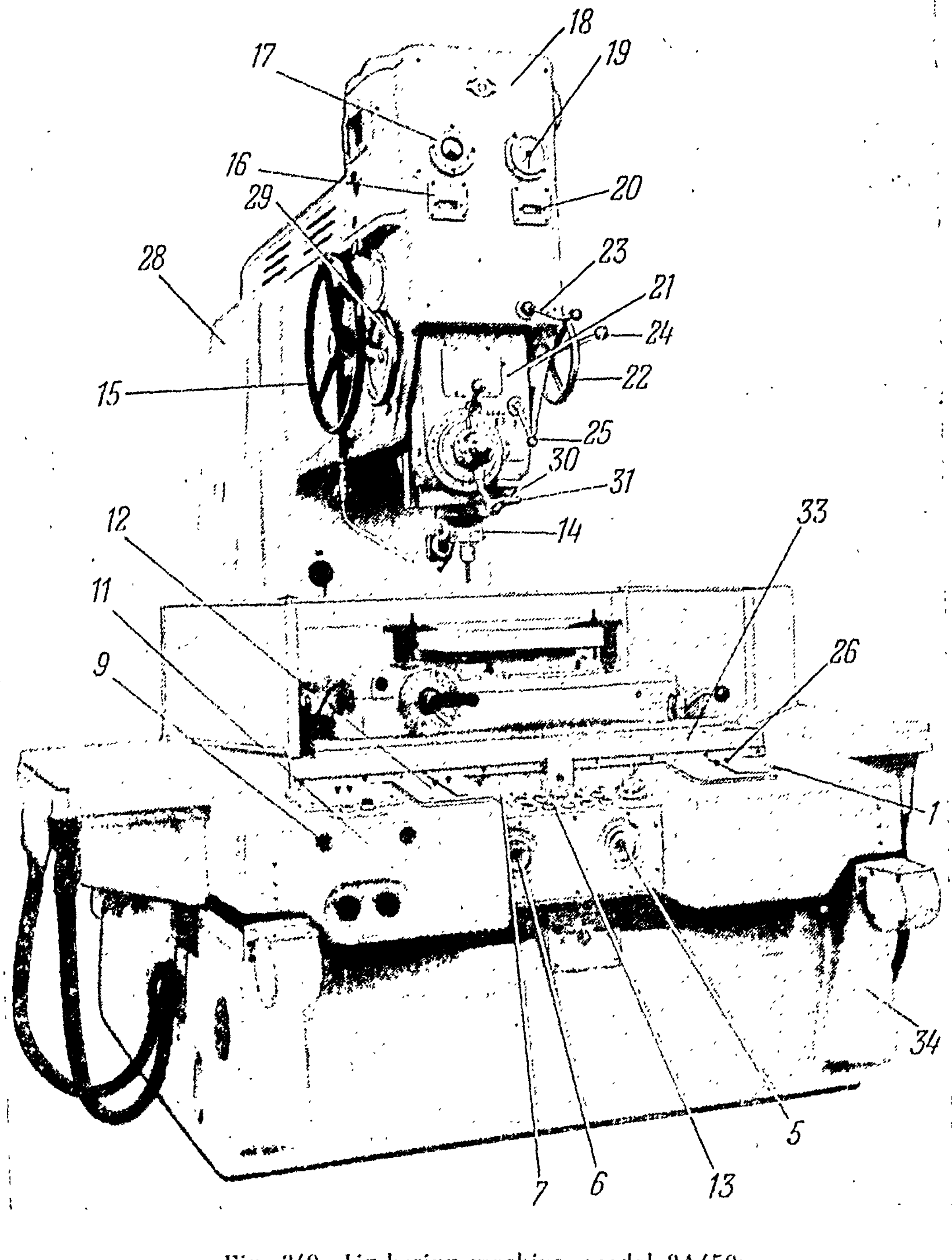


Fig. 349. Jig-boring machine, model 2A450:

1—magnifying glass of cross travel scale; *2*—projector of cross travel scale; *3*—cross travel scale; *4*—saddle traverse drive (*2*, *3* and *4* not shown in the figure); *5*—hand traverse of saddle; *6*—hand traverse of table; *7*—table speed regulator; *8*—coolant system (not shown); *9*—setting dials of co-ordinate preselection mechanism to zero on scale; *10*—control desk of co-ordinate preselection mechanism (not shown); *11*—co-ordinate preselection mechanism; *12*—reading screen for longitudinal table travel; *13*—control desk; *14*—spindle; *15*—handwheel for vertical adjustment of the spindle head; *16*—spindle speed range indicator; *17*—ammeter; *18*—speed gearbox; *19*—spindle speed tachometer; *20*—spindle feed indicator; *21*—spindle head; *22*—handwheel for changing spindle feeds; *23*—lever for disengaging and reversing spindle feed; *24*—lever for clamping the spindle head; *25*—lever of mechanism for disengaging quill feed at preset depth; *26*—reading screen for cross saddle travel; *27*—mechanical system of servomechanism unit; *28*—column; *29*—handwheel for changing spindle speed ranges; *30*—double handle for rapid traverse of spindle quill; *31*—handwheel for micron head feed of the spindle; *32*—device for setting to specified depth (not shown); *33*—table and saddle; *34*—base

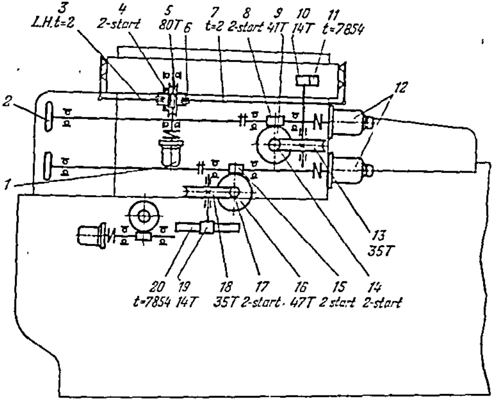


Fig 350. Gearing diagram of the table and saddle of the model 2A450 jig borer

Racks *9* (Fig. 358) of the servomechanism system in the co-ordinate preselection unit are mounted on the table and saddle.

The table is locked by a drive consisting of worm gearing *4* and *5* (Fig. 350), a flexible clutch and electric motor *1* (0 05 kW, 1,390 rpm)

During the speed-up of this motor, worm wheel *5* rotates freely on nut *6* until the driving lugs engage Nut *6* has right-hand thread at one end and left-hand thread at the other. Upon rotation of this nut pushers *7* and *3*, acting through a lever system and brake bands, clamp the table at the required co-ordinate setting with equal force at both sides. The saddle is locked by exactly the same kind of worm reducing gear mounted on the base. The clamping mechanisms are controlled manually from push-button stations.

The construction of the upper part of the jig borer—the spindle head and speed gearbox—is similar to that employed in the model 2B440 and described in Sec. 22-2. The spindle is driven by a d-c electric motor supplied from a magnetic amplifier.

Optical System

Table travel is measured in making co-ordinate settings by means of precise glass scales and an optical system enabling greatly magnified images of the scale graduations and figures, as well as the grating pattern on the reticle (Fig. 351*b*), to be projected onto a screen.

The jig borer has two such optical systems: one for reading the amount of longitudinal travel to position the table and the other for cross travel to position the saddle. Since the two systems are identical, only the table system (Fig. 351*a*) will be considered here.

The light beam passes from the lamp of illuminator *1* through collecting lens *2* which forms an image of the lamp filament on the front focal plane of illuminating lens *3*, thereby illuminating the plane of the graduations of glass scale *5*. Glass strip *4* has no graduations; its purpose is to protect the graduations and figures of scale *5* against dust. The light beam passes through scale *5*, objective *6*, prism *7*, a pair of achromatic wedges *8*, prism *9*, lens *10*, optical flat *11*, and lens *12*, projecting a fivefold magnified image of the scale graduations and figures onto the plane of the grating pattern on reticle *13*.

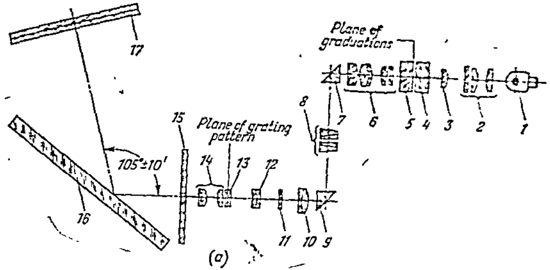
After passing further through projection eyepiece *14* and cover glass *15*, and being reflected from flat mirror *16*, the grating pattern and the scale image are finally projected on screen *17* with a magnification of 125×. Optical flat *11* can be tilted about a horizontal axis to shift the scale image in the plane of the reticle by 0.02 mm.

The optical flat, mounted in the path of the light beam, is tilted by a lever system actuated by a correction bar mounted on the table (or base).

The correction bar compensates for both accumulated and local errors in the graduations of the glass scale. The bar is swivelled to the required angle to correct accumulated errors; the active surface of the bar is made with an appropriately curved surface to correct local errors.

Achromatic wedges *8* can be turned in different directions in respect to each other. This shifts the image of the scale graduations by an amount of up to ±0.5 mm on the screen, in reference to the reticle grating pattern. This enables the visible scale graduation to be set to a whole number in making the initial reading so that the calculation of subsequent co-ordinate settings will be made easier.

The grating pattern of the reticle (Fig. 351*b*) is a transverse scale in which the distance between the two extreme miniature circles (or squares) is equal to 5 mm and corresponds to 1 mm on the glass scale which is projected onto the plane of reticle with a fivefold magnification. The millimetre is divided by the inclined rows into tenths. These tenths are further divided by consecutive uniform displacement of the centres of the 50 circles in each



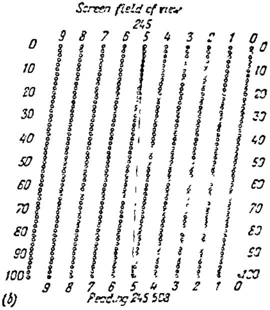


Fig. 351. Optical system of the model 2A450 jig borer:
(a) light path diagram, (b) reticle grating pattern

inclined row of the grating pattern. Thus, the displacement of one circle from the next nearest one, located in the adjacent horizontal line, will be 0.1 : 50 = 0.002 mm.

The inclined rows and horizontal lines of the grating pattern are figured.

The full dimension is read as follows: the figure indicating the number of whole millimetres is projected together with the scale graduation, the number of tenths is equal to the figure at the top of the inclined row intersected by the scale graduation, while the number of hundredths and thousandths is indicated at the end of the horizontal line in which the miniature circle, intersected by the graduation, is located.

In the example illustrated in Fig. 351*b*, the number of whole millimetres, indicated on the scale and projected together with the graduation, is 245, while the reading on the grating pattern is 0.508 mm. Thus, the co-ordinate setting in the given case is 245.508 mm. The grating pattern enables readings of 0.001 mm to be made as well. In this case, the image of the graduation lies on two adjacent circles, covering one half of each one.

During rapid traverse motions of the table or saddle it is necessary to use the steel rules mounted on the machine for making rough readings, since the image of the scale on the screen will be blurred in this case.

The use of an optical measuring system with a grating pattern on the screen requires a large magnification, not less than 100 ×. This does not allow a sufficiently clear-cut image of the scale graduations to be obtained on the ground glass screen.

Electric Circuit and Co-Ordinate Preselection Systems

The electric circuit of the jig borer (Figs. 352, 353, 354 and 355) includes the electric drives of the spindle, table and saddle, clamping mechanisms, and coolant system. It also illuminates the optical system and provides interlocking and protection of certain units under various operating conditions.

Boring spindle rotation, and traverse of the table and saddle are powered by d-c electric motors; induction motors are used to power the table and saddle clamping devices, and the coolant pump. Magnetic and rotary amplifiers are provided to supply the d-c motors.

The electric circuit provides for switching on spindle rotation (Fig. 352), switching it off with braking, stepless variation of spindle speeds, and slow rotation at the "creeping" speed.

The spindle is started in two stages with the aid of magnetic starters, the procedure being controlled by a time-delay relay.

Slow rotation of the spindle can be switched on only after it is stopped. The load on the spindle is checked with an ammeter. Spindle quill travel is restricted by a limit switch.

Electric drives of the table and saddle. The following modes of operation are incorporated in the design of the electric circuit: preselection of the co-ordinate settings from a permanent locating datum; co-ordinate settings made by the operator (without preselection), working feed of the saddle and table for milling operations, and their rapid traverse motions.

The table and saddle can be traversed *simultaneously due to the provision* of two absolutely identical circuits in which all the electric equipment is duplicated.*

The desired mode of operation is set up by a selector switch on the control desk. The auto-positioning system provides for table and saddle travel by amounts set up on the dials of the co-ordinate preselection mechanism (see Figs. 356 and 357). Depending upon the direction of the co-ordinate settings—RIGHT or LEFT, AWAY or TOWARD—the corresponding relays are closed and signal lamps are lit.

The system for reading the co-ordinate dimensions in the given model is based on a servomechanism in which magslips, operating as selsyn transformers, are employed as *measurers of mismatch between the angular positions* of the initial (reference) and terminal units.

The servomechanism in the given model is of the two-channel design, i.e., it has two synchrotransmitters and two synchro-receivers for setting up each of the co-ordinate dimensions (Figs. 357 and 358). One pair of selsyns (transmitter and receiver) is connected into the system with a gearing ratio of 1 : 1 and constitutes the fine reading (*FR*) unit which serves for coincidence *at small angles of mismatch*. The other pair of selsyns is connected through reducing gears and constitutes the coarse reading (*CR*) unit which provides for coincidence at large angles of mismatch. The *CR* selsyns have only one stable coinciding position at angles of mismatch up to 180°.

The *FR* and *CR* errors cannot be *simultaneously applied to the input of* the voltage amplifier since they would distort each other and, at certain values, would be in opposition. This possibility is excluded by the provision in the circuit of a relay selector for coarse and fine readings, consisting of a rectifier *GR11* (Fig. 354), polarized relay *PR* and relay *AR1*.

At large angles of mismatch, control
coarse-reading synchro-receiver *SRC* (F
function of the fine-reading synchrotransmitter SIt The voltage of the coarse-reading selsyns, regulated by resistor *R27* (Fig. 354) is applied to the input of the selector. As this voltage drops, relay *PR* opens and its contacts cut out relay *AR1*. The contacts of *AR1* in turn, switch off the rapid traverse signal and switch in the fine-reading selsyns. *Then the voltage of the fine-*

*In the diagrams, figure 1, preceding the symbol designating the various devices and machines, indicates that the given item is part of table drive; figure 2 refers to the saddle drive. To simplify the description, it will concern only the table drive.

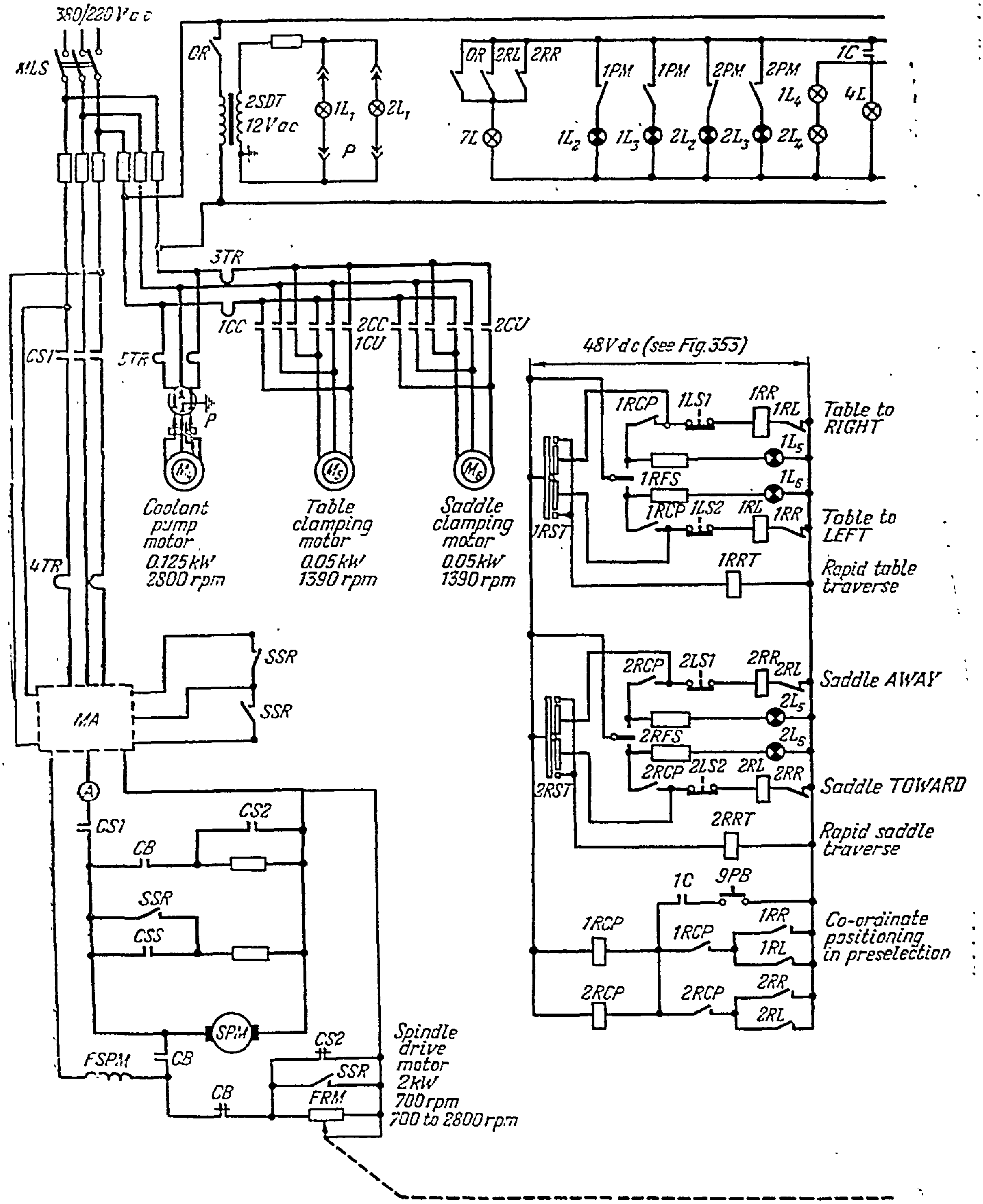


Fig. 352. Elementary diagram of the electric circuit (without the

A—ammeter; MLS—main line switch. Travel-restricting limit switches: $1LS$—spindle quill travel; for starting rotary amplifier RA; $1C$—no-voltage protection; $1CB$—for braking; $CS1$—1st stage in star for clamping table and saddle; $1CU$ and $2CU$—for unclamping table and saddle. Push buttons: $1PB$—spindle; $5PB$—starting spindle; $6PB$—slow rotation; $7PB$ and $8PB$—clamping and unclamping the Illuminating lamps: $1L_1$ and $2L_1$—optical system; $1L_4$ and $2L_4$—dials for co-ordinate preselection; and unclamping; $3L$—power supply ON; $1L_5$, $1L_6$, $2L_5$ and $2L_6$—direction of travel; $6L$—lamp of cen winding of motor SPM. Relays: TR—thermal relay; OR—relay for optical system illumination; SSR—$1RL$ and $2RL$—saddle traverse TOWARD, table traverse to LEFT; $1RRT$ and $2RRT$—rapid traverse co-ordinate positioning relays. Time-delay relays: TRO—for optical system illumination; TRS—$1RST$ and $2RST$—table and saddle traverse speed regulators; FRM—field regulator of motor SPM. amplifier; $2S$—

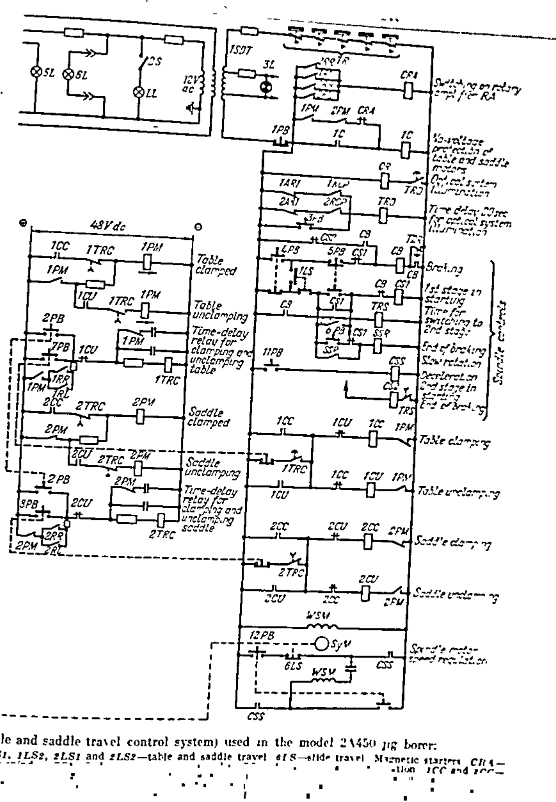


table and saddle travel control system) used in the model 2A450 jig borer:
1LS1, 1LS2, 2LS1 and *2LS2*—table and saddle travel *6LS*—slide travel. Magnetic starters *CRA*— ... tion *1CC* and *2CC*—

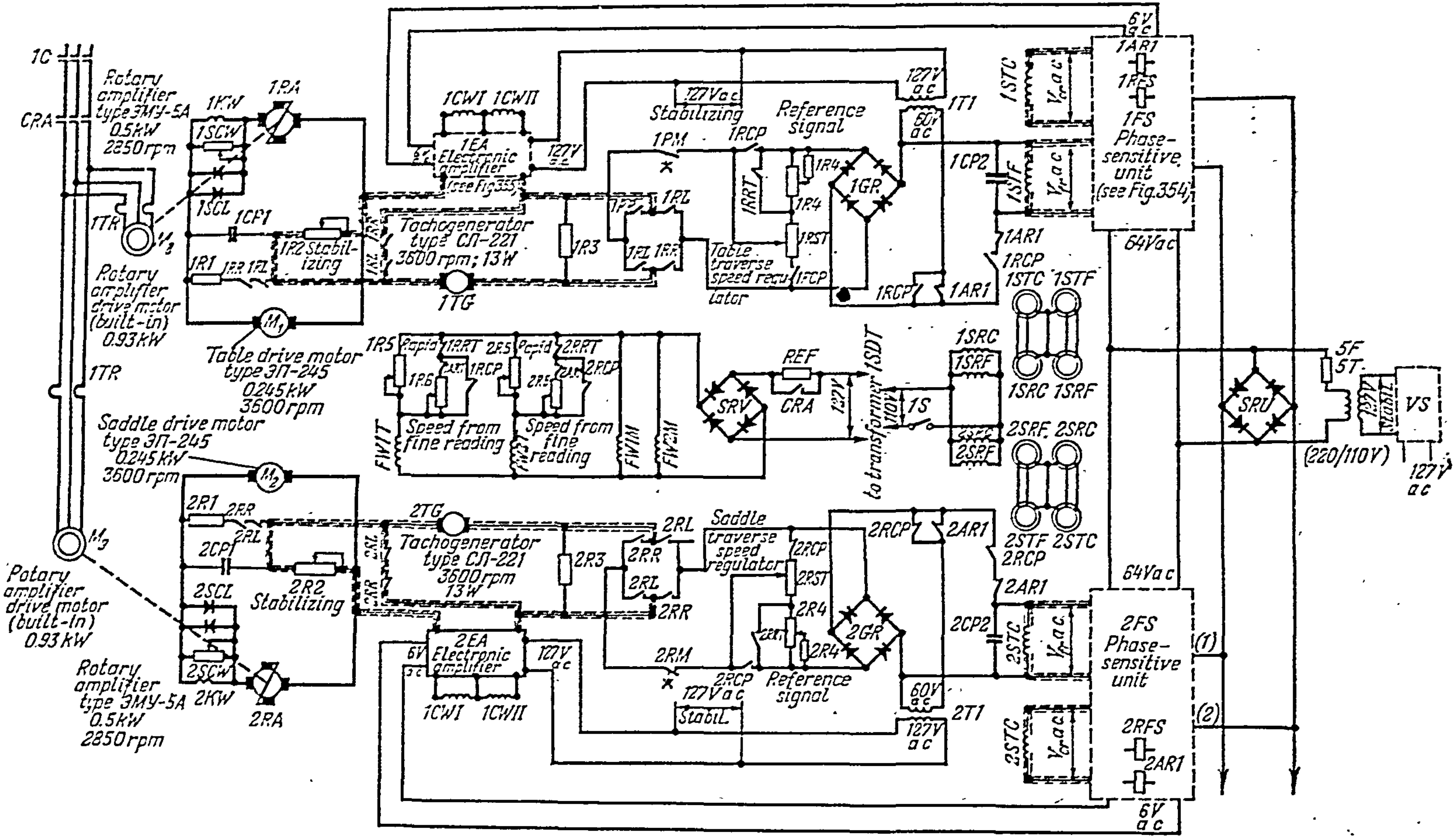


Fig. 353. Elementary diagram of the table and saddle travel control circuit used in the model 2A450 jig borer:

Rectifiers: *1GR* and *2GR*—germanium rectifiers; *SRV* and *SRU*—selenium rectifiers. Capacitors: *1CP1* and *2CP1*—antihunt feedback; *1CP2* and *2CP2*—for filtering out upper harmonics. Windings: *1KW* and *2KW*—compensating windings of rotary amplifier *RA*; *FW1M* and *FW2M*—field windings of motors *1M* and *2M*; *FW1T* and *FW2T*—field windings of tachogenerators *1TG* and *2TG*; *1CWI*, *1CWII*, *2CWI* and *2CWII*—control windings of rotary amplifiers *1RA* and *2RA*; *1S*—selector switch for co-ordinate preselection; *5F*—fuse; *1RST* and *2RST*—table and saddle speed regulators. Relays: *1RFS* and *2RFS*—phase-sensitive relays; *1AR1* and *2AR1*—relays for changing over from coarse- to fine-reading selsyns; *1TR* and *2TR*—thermal relays; *1SCL* and *2SCL*—selenium stack current limiters. Resistors: *1R1* and *2R1*—braking resistors; *1R2* and *2R2*—antihunt feedback resistors; *1R3* and *2R3*—protective resistors; *1R4* and *2R4*—regulating resistors; *1R5* and *2R5*—rapid traverse resistors; *1R6* and *2R6*—traverse from fine-reading selsyn; *REF*—economizing field resistor. Selsyns: *1STC* and *1STF*—coarse- and fine-reading selsyns transmitting table traverse values; *2STC* and *2STF*—coarse- and fine-reading selsyns transmitting saddle traverse values; *1SRC* and *1SRF*—coarse- and fine-reading selsyn receivers controlling table traverse; *2SRC* and *2SRF*—coarse- and fine-reading selsyn receivers controlling saddle traverse; *VS*—voltage stabilizer. Transformers: *1T1* and *2T1*—isolating transformers; *5T*—step-down transformer; *1SCW* and *2SCW*—shunts of compensating windings

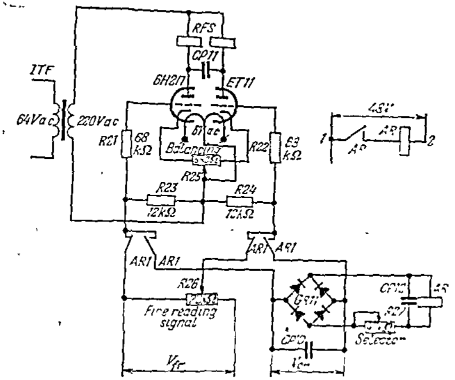


Fig. 354. Elementary diagram of the phase-sensitive unit:

1TF—isolati...
R25—balanc...
regulator of...
RFS—phase-...

reading selsyn is fed into the input of the phase-sensitive device in place of the coarse-reading selsyn voltage.

To amplify the tracing error signal, as well as the signal from the stabilizing devices, both in voltage and power, to values of sufficient magnitude to operate the actuating motor, an electronic amplifier *1EA* (Figs. 353 and 355) is used in conjunction with rotary amplifier *1RA* (Fig. 353).

Connected to the electronic amplifier output are control windings *1CWI* and *1CWII* of rotary amplifier *1RA* which supplies the armature winding of motor M_1 for powering table traverse.

When there are mismatch angles, the difference between the voltage of the reference signal, taken from the winding of the synchrotransmitter *1STF* or transformer *1TI*, and of tachogenerator *1TG* is applied to the input of electronic amplifier *1EA*.

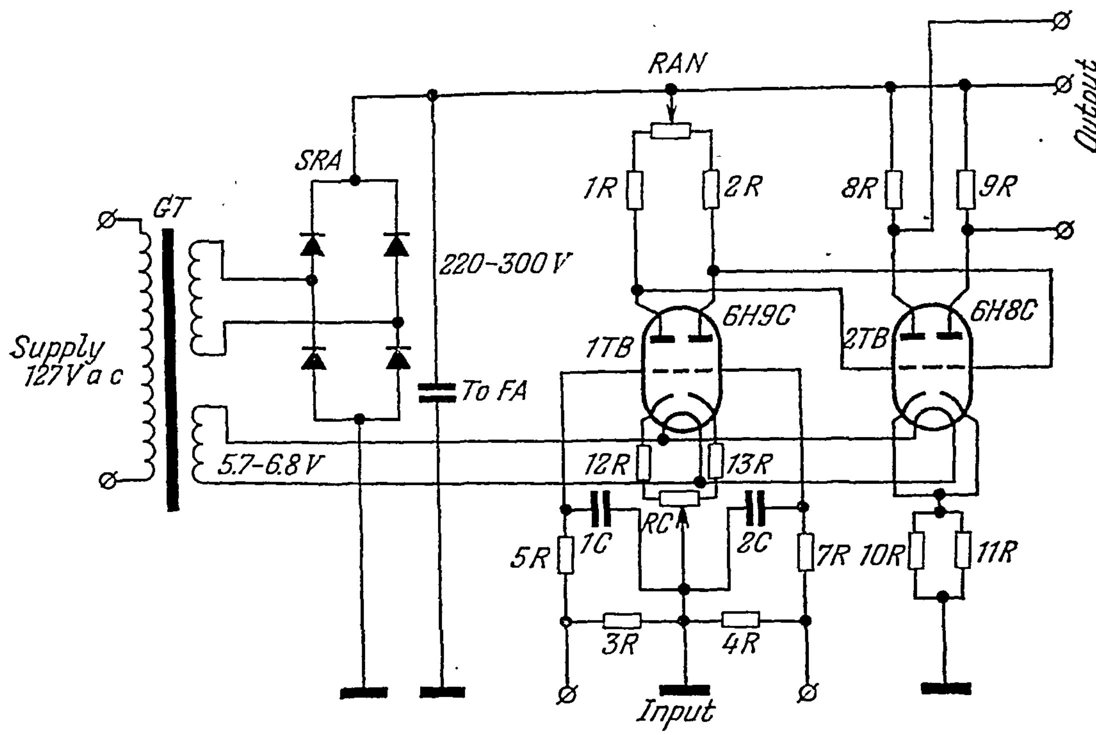


Fig. 355. Diagram of the electronic amplifier

Upon an increase in voltage of the reference signal, the voltage at the input of electronic amplifier *1EA* likewise increases. This increases the excitation and voltage of rotary amplifier *1RA* and, as a result, the speed of motor M_1 is raised.

In a similar way, a drop in voltage of the reference signal reduces the speed of motor M_1 correspondingly.

If the reference signal has a constant value, the speed of the electric motor may be reduced as a result of increased load, etc. This will reduce the voltage of the tachogenerator and increase that applied to the input of electronic amplifier *1EA*, and lead to an increase in the excitation and voltage of rotary amplifier *1RA*, thereby restoring the speed of the electric motor.

Thus a constant speed of table traverse is maintained.

The field windings *FW1M* and *FW1T* of motor *1M* and the tachogenerator, respectively, are supplied by the application of the voltage of selenium rectifier *SRV* to them.

Resistor *REF* is connected in series with the field windings of the motors to reduce their heating as they are switched off. The electronic amplifiers are supplied by a stabilized voltage.

Clamping and unclamping are effected by pressing push buttons on the control desk.

Using the preselection device, readings can be made in setting to co-ordinate dimensions with an accuracy within 0.1 mm. The units are positioned automatically within 0.5 mm of the specified co-ordinate settings. Fine settings require hand traverse, checking the position on the screens.

The operator uses regulators *1RST* and *2RST* (Fig. 353) for manual con- [illegible] tachogenerator, thereby increasing the speed of motor M_1. Table travel is restricted in the extreme positions by limit switches.

Co-Ordinate Preselection Mechanism

This mechanism (Fig. 356) is a two-stage reducing gear with spur gearing 15, 12, 13 and 11, the total ratio being $\frac{1}{30}$. The co-ordinate dimensions for the setting are set up on the control desk of the auto-positioning unit with comparatively low accuracy before the positioning motions take place. This *may be done during the time the present hole is being machined.*

A command is carried out after a push button is pressed on the control desk. The given dimension and the performance accuracy ensure *traverse* of the table and saddle to a point close to their final positions. Further positioning is done by hand, checking against the readings on the viewing screens *of the optical system* (see Fig. 351*a*). The co-ordinate preselection mechanism (Fig. 356) consists of two independent sections, identical in construction. *One controls table traverse and the other, saddle traverse.*

Dimension-setting shaft *1* is linked by coupling *14* to fine-reading selsyn *SF*; shaft *4* is linked to coarse-reading selsyn *SC*. Mounted freely on shaft *4* is dial *6* for reading off tenths of a millimetre. Dial *3* for reading off tens of millimetres is secured to this shaft. Dial *6* is linked to dial *3* through gears *5* and *2*, *2* and *16*, *15* and *12*, *13* and *11*, the ratio being

$$i = \frac{42}{77} \times \frac{16}{80} \times \frac{16}{96} = \frac{1}{55}$$

One revolution of fine-reading dial *6* corresponds to a travel of 40 mm while half a *revolution of* coarse-reading dial *3* corresponds to 1 100 mm.

The gearing of the mechanism is designed so that in each pair of gears, the larger gear *comprises two parts* between which a spiral spring *10* is arranged. The spring tends to rotate the two parts in opposite directions, thereby taking up all the backlash in the *mating gears*.

Discrepancies between the readings on the dials and on the precise glass scales (see Fig. 351) are eliminated as follows. After shifting the image of the

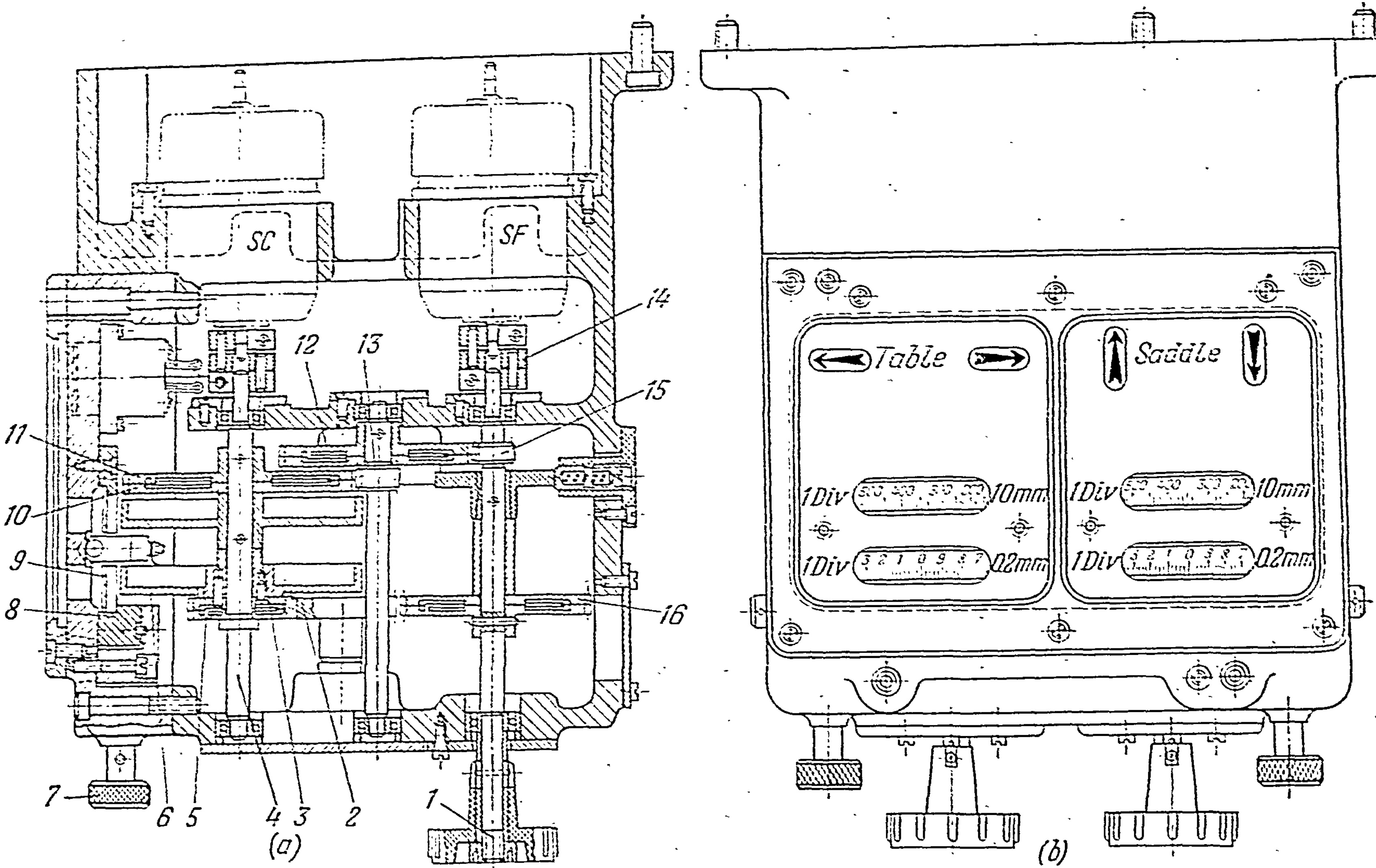


Fig. 356. Co-ordinate preselection mechanism of the model 2A450 jig borer:
(a) development; (b) top view

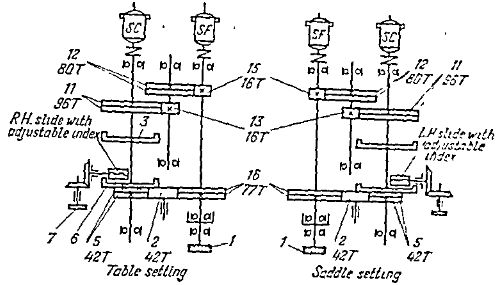


Fig. 357. Gearing diagram of the co-ordinate preselection mechanism

Resistor *1R5* is cut in in series with the field winding of the tachogenerator to obtain a substantial increase in the speed of motor *1M*, while resistor *1R6* is cut in for a slight speed increase when operating from the fine-reading selsyn.

In operation with preselection of the co-ordinate settings, the direction of table or saddle travel is determined by the sign of the mismatch angle, i.e., the direction of rotation of the rotors in the synchrotransmitters *1STF* and *1STC*. When the operator turns these selsyns, the mismatch voltage is set up over their windings. This voltage is applied to the input of the phase-sensitive unit (Fig. 354).

Depending upon the condition of relays *PR* and *AR1*, various voltages are applied to the grid of the type 6H2П tube. The anode circuit of this tube is supplied with stabilized a-c current. As various mismatch voltages (in phase with the anode circuit voltage or shifted by 180°) are applied to the tube grid, either of the contacts of phase-sensitive relay *1RFS* (Figs 353 and 354) is closed. The relay *1RFS* prepares the coil circuit of relay *1RR* (Fig. 353) for accomplishing table traverse to the right, and that of relay *1RL* for traverse to the left.

The direction of traverse is indicated by the signal lamps. The electric circuit incorporates an interlocking feature preventing the drive motors of the table and saddle from being switched on until the units are unclamped

scale graduation by means of optical wedge *8*, it is necessary to shift the index line on indicating plate *9* (Fig. 356) by the same amount. This is done by rotating head *7* which shifts slide block *8*, by means of bevel] gears and a nut and screw, to which plate *9* is secured.

Mechanical System of the Servomechanism Arrangement

The unit shown in Fig. 358 is a two-stage reducing gear with the spur gears *7* and *4*, *3* and *2*, and having a total ratio of 1 : 30. On one end driving shaft *5* is linked to rack *9* of the table or saddle through rack pinion *6*. On its other end, it is linked through coupling *8* to fine-reading selsyn *SF*.

Output shaft *1* is linked to coarse-reading selsyn *SC*. An electrical linkage exists between the co-ordinate preselection mechanism and the servomechanism arrangement. The reducing gear of the servomechanism is secured to the saddle (or base, as the case may be) through pivot pin *10*, while spring *11* holds the rack pinion against the rack, thereby eliminating backlash.

Table and Saddle

The table and saddle each has one flat way and one V-way of the antifriction roller type. The coarse-reading steel rule, clamping band, optical glass scale, correction bar, the rack for table traverse and rack of the servomechanism are mounted on the bottom and side surfaces of the table.

The screens for longitudinal and cross travel, co-ordinate preselection mechanism and the control desk of the jig borer are arranged on the front wall of the saddle.

Inside the saddle are mounted the optical projecting system, table and saddle reducing gears and the table clamping reducing gear. The electric motors of the table and saddle traverse drives, and the mechanism of the table servomechanism arrangement are mounted at the rear part of the saddle.

The traverse drive motors are automatically switched off at the extreme positions of the table and saddle.

The described construction is an improvement over the previously manufactured model 2A450. The electric circuit has been completely changed to permit the table and saddle to be traversed simultaneously; the method of obtaining the final setting to the specified co-ordinate dimensions has been revised; the optical system has been improved; the spindle drive has been redesigned; a different method of effecting stepless speed variation has been employed; etc.

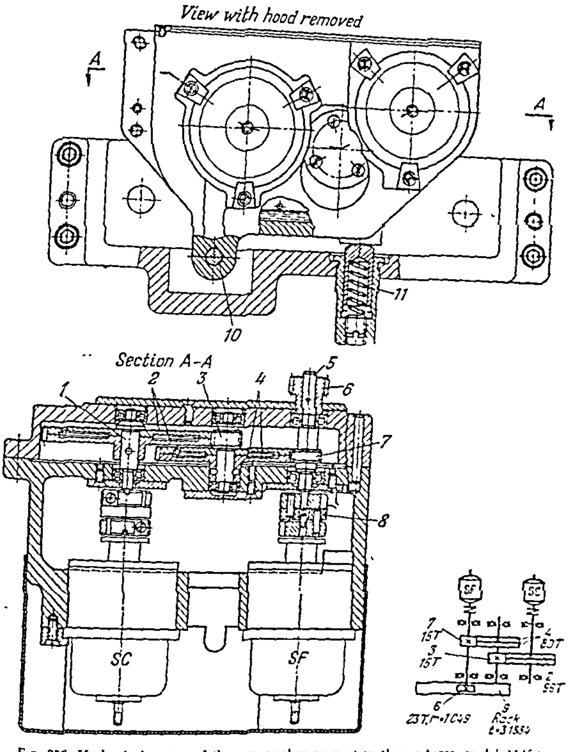


Fig. 358. Mechanical system of the servomechanism unit in the jig borer, model 2A450 (development and gearing diagram)

CHAPTER 23
TOOL AND CUTTER GRINDERS

23-1. Types

Tool and cutter grinders are intended for sharpening both new and dulled cutting tools. They find application in the mass production of tools in special tool plants, as well as in the tool rooms of all engineering plants, while some types of tool grinders are also used in the machine shop.

Strictly speaking, machines for sharpening tools can be classified into two general groups: (1) tool grinders for sharpening and lapping cutting tools made of high-speed steels, or tipped with cemented carbides, and (2) machines for the nonabrasive sharpening and lapping of cutting tools.

The second group covers machines for electrolytically assisted grinding, and for the electrical-discharge sharpening and lapping of cutting tools.

The great majority of tool sharpening machines operate with some type of abrasive tool. The use of diamond wheels for sharpening and lapping carbide-tipped tools is becoming more and more widespread practice in recent years.

The application of diamond wheels in place of ordinary abrasive ones leads to a substantial increase in productivity. In many cases, tools sharpened with metal-bonded diamond wheels require no subsequent lapping.

Tool and cutter grinders can be classified as universal and single-purpose models.

Various kinds of cutting tools, such as single-point tools, reamers, core drills, milling cutters, gear-cutting tools, etc., can be sharpened in a universal tool and cutter grinder. Single-purpose tool grinders are designed for sharpening only one definite type of cutting tool, such as twist drills, single-point tools, hobs, broaches, etc.

Special machines are employed to perform tool lapping operations. Carbide-tipped tools can also be lapped in tool grinders designed for both sharpening and lapping.

Until comparatively recently, all tool sharpening and lapping were done by offhand methods. At the present time, some degree of automaticity has been introduced. Certain Soviet tool grinders, for example model B3-32 for twist drills and B3-49 for reamers, operate on automatic cycles. Hob grinder, model 3662, drill-point grinders, models 3659A and 3659M, and others operate on semiautomatic cycles.

An automatic drill sharpening machine, model НН-3-1, has been developed in the USSR. It is based on a continuous process that sharply increases the production capacity.

This chapter deals with only three tool grinders: a universal tool and cutter grinder, a semiautomatic drill-point grinder, and a semiautomatic hob grinder.

Universal tool and cutter grinders, models 3A64 and 3A64M, though extensively employed in Soviet plants, do not meet all the requirements made to up-to-date machines for the diamond-wheel sharpening of tools.

The need of grinders capable of ensuring efficient performance in diamond-wheel tool sharpening has led to the modernization of these widespread models. A description of the necessary alterations is treated in the following section.

23-2. Universal Tool and Cutter Grinder, Model 3A64, and Its Modernization

This grinder (Fig. 359) consists of the following principal units: base *1*, table unit *2* and wheelhead *3*.

Base *1* is a box-shaped grey iron casting on top of which ways are provided for travel of the saddle.

The table unit (Fig. 360) consists of saddle *17*, longitudinal table *15* and swivel table *18*. Saddle *17* is traversed along the base ways in the crosswise direction by means of screw *14* and nut *13*, when one of the handwheels *10* is rotated. This handwheel is duplicated for convenience in handling the grinder. Longitudinal table *15* travels along roller ways *12* of the saddle.

Rapid hand traverse is accomplished by turning handwheel *16* which drives the table through pinion *24* and rack *25*. Slow table traverse is obtained by turning handwheel *19* which is fastened to the housing of a planetary reducing gear having a ratio of 1 : 10. Side play of the longitudinal table is eliminated by the provision of ball bearings *32* and *35*, two each, mounted on pins at the ends of the saddle. These bearings are arranged on the two sides of and guide longitudinal ridge *26* underneath the longitudinal table. The pins of bearings *35* are secured in rocking levers *34* and are forced by springs *33* against the side of ridge *26* to take up the clearance in the system.

Adjustable dogs *20*, held in a T-slot in the front wall of the table, limit longitudinal table travel with the aid of stationary stop *23* mounted on the saddle.

Swivel table *18* is located by pivot *11* on the longitudinal table. The swivel table is set to the required angular position by means of handle *31*, screw *30* and nut *28*, secured to the longitudinal table, and strip *27* and pin *29* mounted

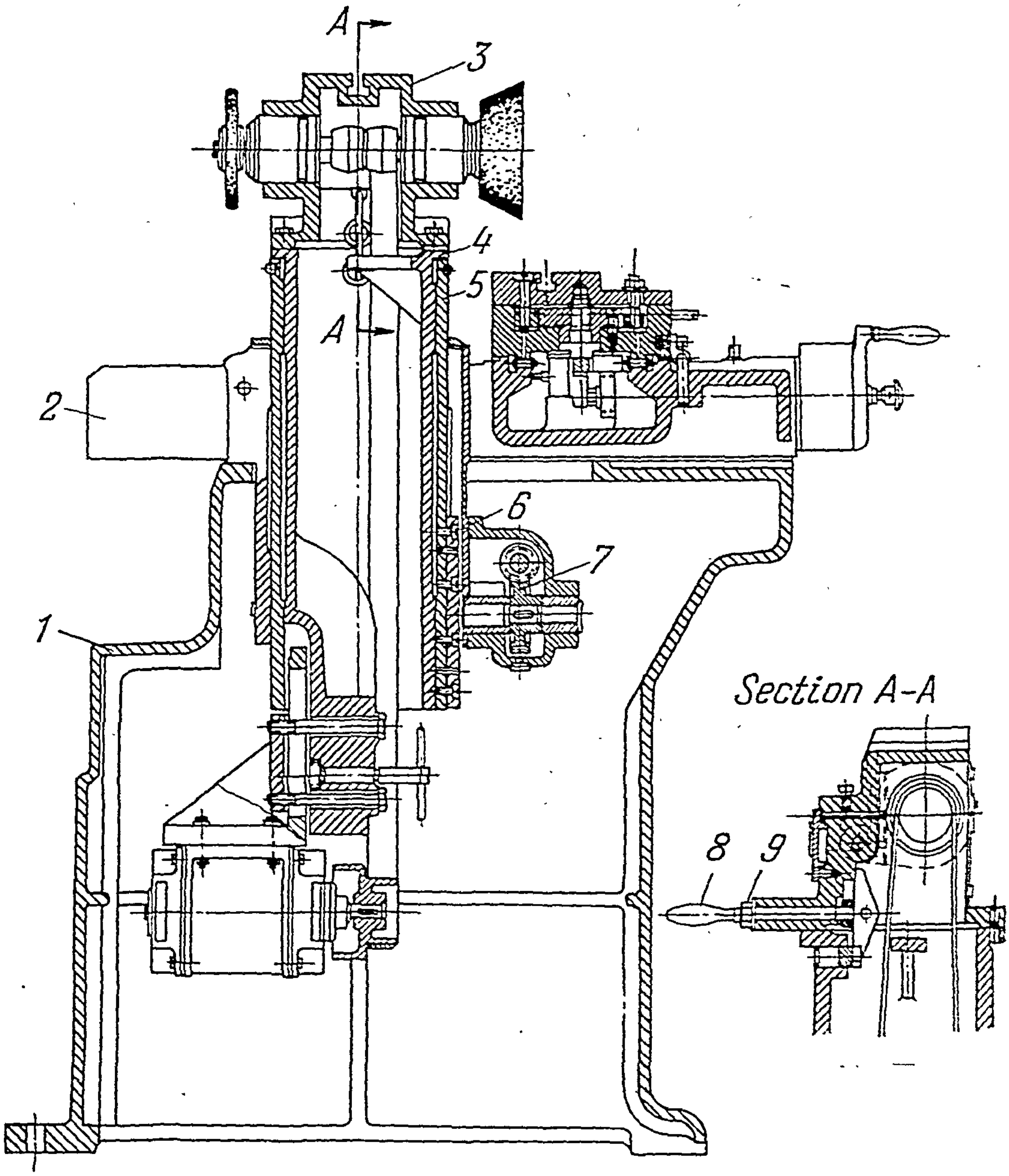
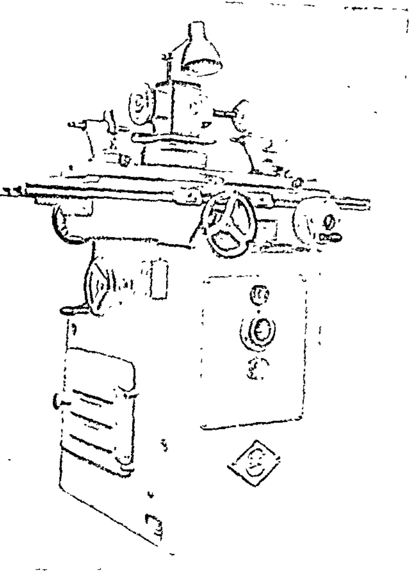


Fig. 359. Universal tool and

on the swivel table. The amount of swivel is read off on the scale of strip *27*. Each division of this scale is equal to a taper of 0.01. An additional scale *22*, graduated in degrees, is fastened on longitudinal table *15*.

The swivel table is clamped in the required position by nut *21*.



cutter grinder, model 3A64

Wheelhead unit *3* (Fig. 359) consists of sleeve *5* and inner column *4* on whose top surface the spindle housing is secured. The machined pad on the top of the spindle housing is for mounting and clamping the centre-setting attachment, internal grinding attachment, etc. The wheelhead unit is raised

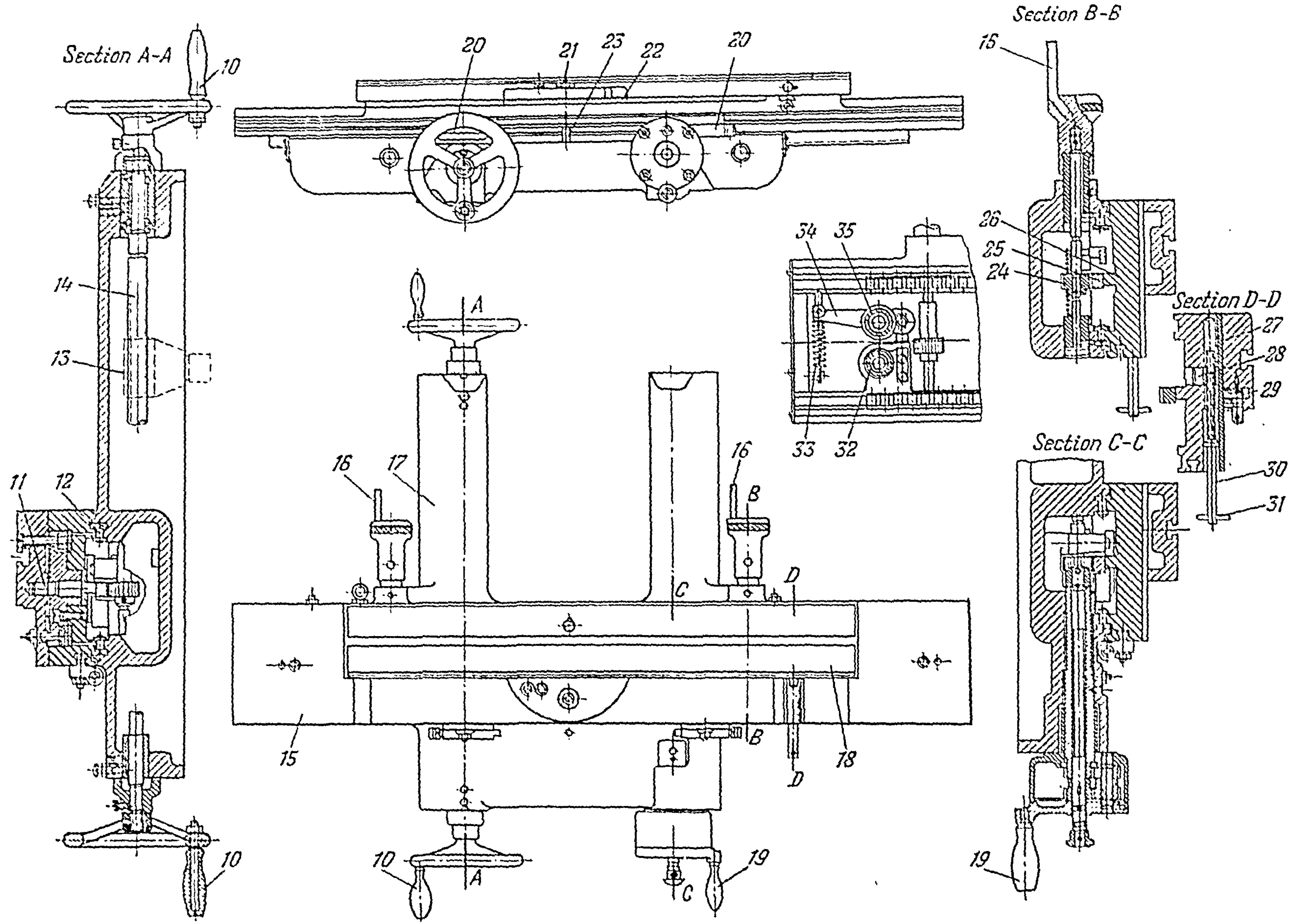


Fig. 360. Table unit of the model 3A64 grinder

or lowered by means of a handwheel through worm gearing *7*, a rack pinion and rack *6*, fastened to sleeve *5*. To set the wheelhead to an angle, nut *9* is released, column *4* is swivelled in sleeve *5* by handle *8*, and then nut *9* is retightened. The angle of swivel is read on a scale engraved on sleeve *5*.

The spindle is driven through a flat belt by the 0.65-kW electric motor, mounted on an angle bracket at the lower end of sleeve *5*. The wheel spindle can run at either 3,730 or 5,600 rpm.

The capacity of the tool grinder is extended by the various attachments that can be furnished. These include the cylindrical, internal and surface grinding attachments; attachments for sharpening form-relieved milling cutters, face milling cutters, hobs, blade-type die-head chasers, taps, long reamers, twist drills, core drills and other tools; a universal head, right- and left-hand footstocks, driving dogs and centre-setting attachment. Attachments that are to be mounted on the upper ground surface of the swivel table are clamped by T-bolts.

[illegible] the model 3A64 grinder [illegible] ice grinding in addition [illegible] 4, the universal tool and cutter grinder, model 3A64M, has four speeds of wheel spindle rotation obtained by means of a two-speed electric motor and a two-step V-belt drive. The rating of the drive motor has been increased to 0.75/1 kW at 1,420/2,850 rpm. The corresponding wheel spindle speeds are 2,900 and 5,800 or 2,000 and 4,020 rpm. The wheelhead can be raised or lowered from two operator's positions by means of worm gearing and a rack-and-pinion. The amount of elevation has been increased in comparison with the earlier model.

As mentioned above, these universal tool and cutter grinders require certain modifications before they can be efficiently used for diamond-wheel tool sharpening operations. In particular, coolant must be used in sharpening tools with metal-bonded diamond wheels. Sharpening can be performed dry with resinoid-bonded diamond wheels, but their wear will increase.

In modernizing* these machines, facilities are provided for both wet and dry sharpening with abrasive and diamond wheels

The modernization of these grinders consists of the following principal measures: (1) a fine cross feed mechanism, providing infeeds of 0.005-0.01 mm, is to be added, and (2) the rigidity of the grinder is increased by the installation of a new wheelhead (Fig. 361).

More rigidity and higher accuracy of the wheel spindle have been achieved in the new construction of the wheelhead by increasing the diameter of the

*Standard Project for the Modernization of Universal Tool and Cutter Grinders, Models 3A64 and 3A64M, TSNIITMASH, Moscow, 1963.

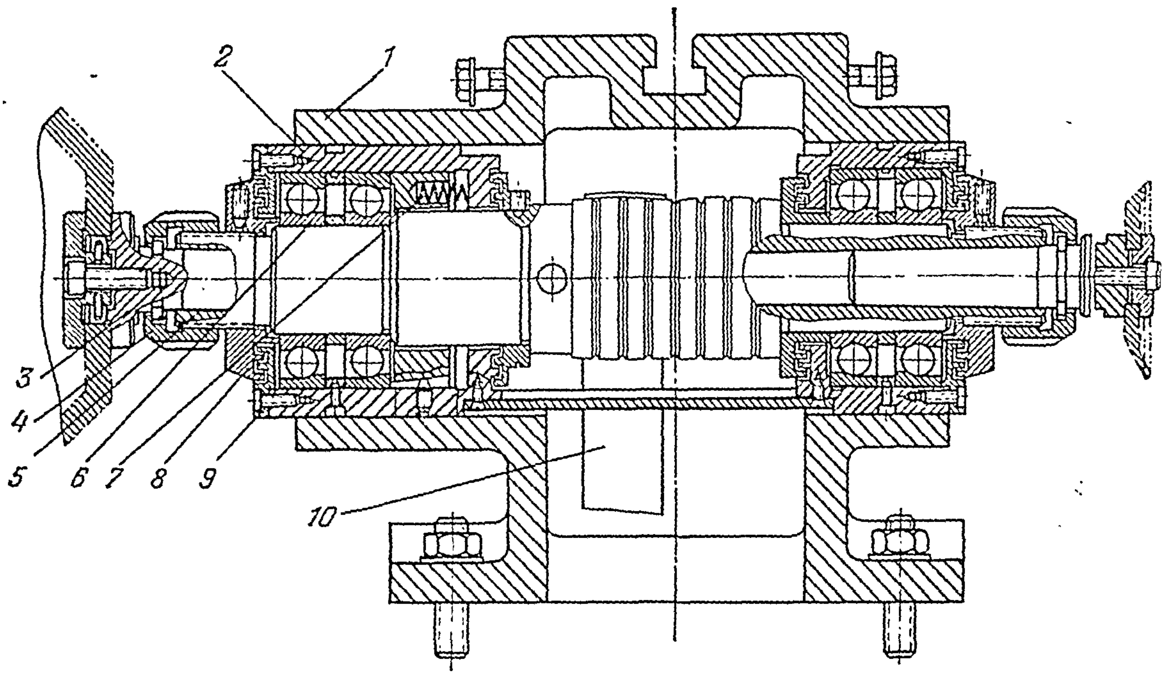


Fig. 361. Modernized wheelhead:

1—housing; *2*—sleeve; *3*—wheel arbor; *4* and *8*—nuts; *5*—wheel spindle; *6*—single-row angular-contact ball bearing (class A); *7*—spring; *9*—flange; *10*—endless flat belt of plastic

spindle bearing journals and by using class A angular-contact ball bearings in this unit. The outer rings of the bearings in the left-hand support are spring-loaded to eliminate excess clearances and to retain the accuracy of rotation. A labyrinth packing of improved design has been used to seal the spindle bearings. The wheel arbors are seated in tapered holes in the spindle. This ensures more rigid clamping of the wheels than when they are mounted on an external taper on the spindle nose.

As a measure against vibration, it is advisable to drive the spindle with an endless flat belt instead of V-belts. A flat belt of plastic is preferable since its thickness is more uniform over its length and its flexibility and durability are much higher than those of a rubberized flat belt.

Another measure that will efficiently combat vibration is to install a wheel drive motor that has been properly dynamically balanced.

A coolant system is built into the grinder in the process of its modernization, and special guards serve as protection against splashing and to collect the used coolant which drains back to the tank. A special enclosed wheel guard serves the same purpose.

23-3. Semiautomatic Grinder, Model 3659A, for Sharpening Twist Drills and Core Drills

The model 3659A semiautomatic grinder (Fig. 362) is intended for sharpening right-hand twist drills, and three- and four-flute core drills, from 10 to 80 mm in diameter, with relief angles from 6° to 17° and point angles from 70° to 140°. Tools with double angle points can also be sharpened.

The lip relief surfaces of drills are ground helically, in sharpening, by the tapered face of the wheel.

The grinder has the following motions:

(1) grinding wheel rotation;

(2) rotation of the tool being sharpened which is held in a chuck;

(3) reciprocation of the grinding wheel in a direction along the axis of the grinder spindle;

(4) planetary motion of the wheel in a plane square to the axis of the grinder spindle;

(5) power and hand infeed of the tool being sharpened to the wheel.

The gearing diagram of the grinder is illustrated in Fig. 363. Rotation is transmitted to the wheel spindle from an electric motor (2.8 kW, 1,420 rpm) through a V-belt drive $\frac{155 \text{ dia}}{115 \text{ dia}}$ with idler pulley *20*. From the same motor rotation is transmitted through a V-belt with pulleys $\frac{75 \text{ dia}}{242 \text{ dia}}$, gears $\frac{16}{78}$ (gear $78T$ is freely mounted), clutch *13* and gears $\frac{62}{75} \times \frac{75}{62}$ to quill *7* of the spindle. A safety clutch, built into the 242-mm pulley, protects the mechanisms against overloads. Clutch *13* is to engage or disengage chuck rotation with the clamped tool, as well as planetary rotation and axial reciprocation of the wheel spindle. The latter three motions are interlinked kinematically and serve to produce the helicoidal lip relief surface on the tool being sharpened.

The planetary motion of spindle *16* with the grinding wheel favours more uniform wheel wear. This motion is due to the eccentric position of wheel spindle *16* in reference to the axis of quill *7*. The latter runs in split tapered sleeve bearings. The wheel spindle is mounted in angular-contact ball bearings fitted in the eccentric bores of the quill.

Cylindrical cam *8*, mounted on the quill, has three different rise curves arranged concentrically. The curve used in each particular case depends upon the diameter of the drill being sharpened and its lip relief angle. Cylindrical cam *8* is held by two springs *6* against stop *9* which is secured to the wheelhead housing.

Stop *9* has three different lugs which are brought into engagement with the corresponding curve of the cam by shifting lever *15* (Fig. 362). This changes

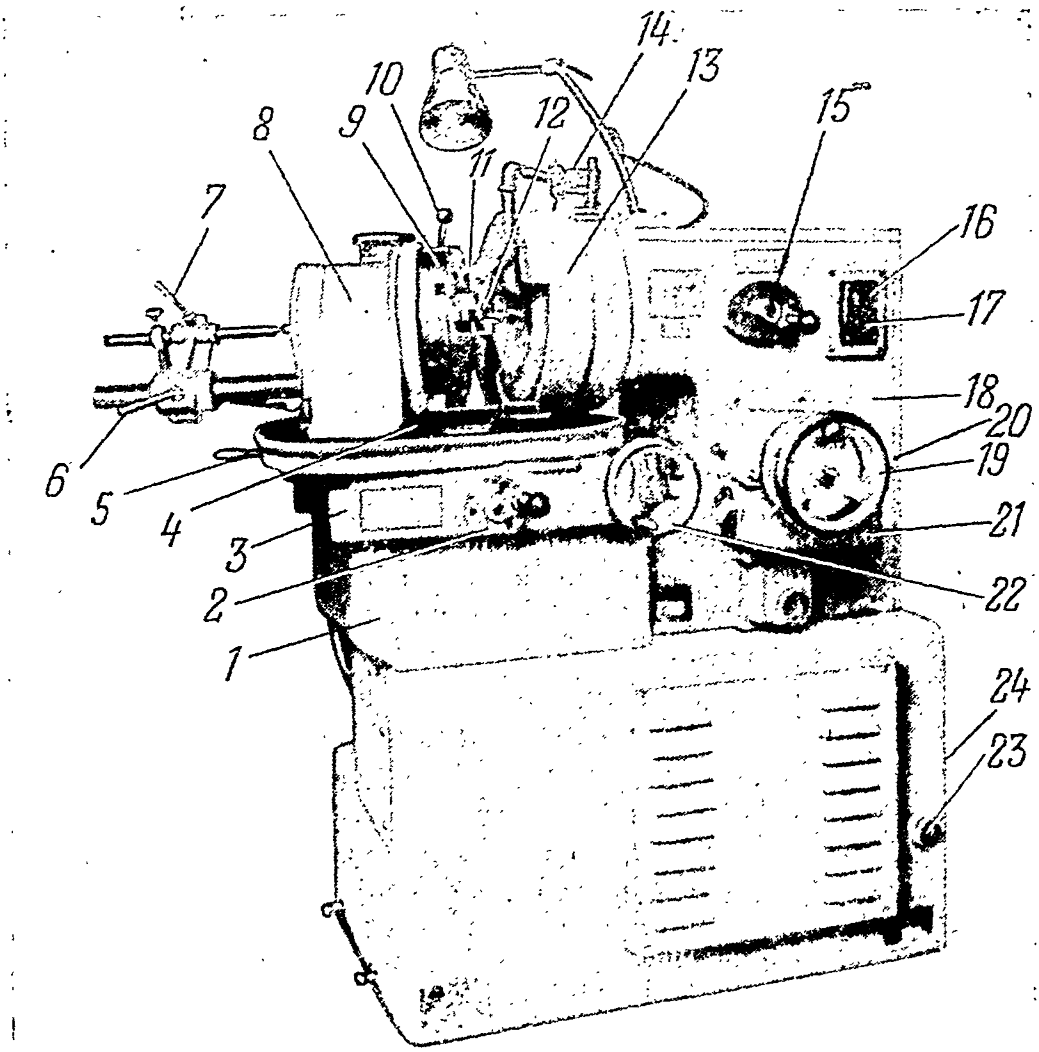


Fig. 362. Semiautomatic grinder, model 3659A, for sharpening twist drills and core drills: 1—base; 2—lever for setting the sliding key of the gearbox; 3—carriage; 4—nut for clamping the swivelling member of the carriage; 5—handle for swivelling the carriage member; 6—lever for clamping the rear centre bracket; 7—lever for clamping the rear centre; 8—chuck; 9—lever for operating the chuck jaws; 10—handle of the wheel dressing mechanism; 11—swinging stop; 12—nut for adjusting the stop to the web thickness; 13—wheel spindle; 14—coolant cock handle; 15—lever for setting to the lip relief angle; 16—START push button; 17—STOP push button; 18—wheelhead; 19—handwheel for engaging the power infeed, chuck rotation and the planetary and axial motion of the wheel spindle; 20—lever for setting the rate of infeed; 21—infeed mechanism; 22—handwheel for carriage traverse; 23—screw for adjusting the spring of the idler pulley; 24—main line switch

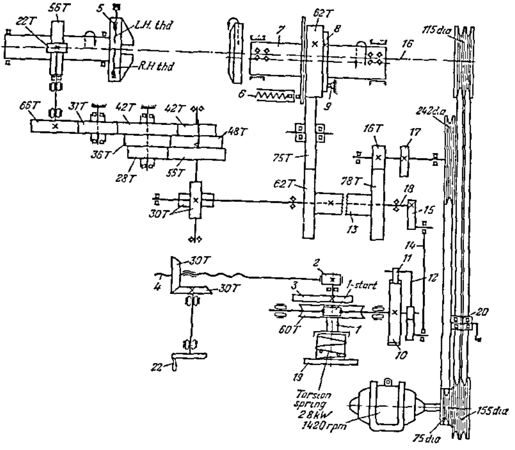


Fig. 363. Gearing diagram of the semiautomatic grinder, model 3659A

the amount of axial travel of the spindle and, consequently, the lead of a helicoidal surface when one is ground. The possibility of varying the lead of the helicoidal surface is used to vary the lip relief angle of the tool being sharpened.

In accordance with the size of the drill being sharpened, cylindrical cams are used for small, medium and large diameters. Chuck *5* (Fig. 363) is driven from the gear train for rotation of quill *7*.

The gear train equation for the given case is

$$1 \text{ revolution of the cam} \times \frac{62}{62} \times \frac{30}{30} \times i \times \frac{42}{66} \times \frac{22}{56} = \frac{1}{K}$$

Thus

$$i = \frac{4}{K}$$

where K_4 = corresponding gearbox ratio $\left(K = \frac{56}{28}, \frac{48}{36} \text{ or } \frac{42}{42}\right)$ selected to suit the tool being sharpened

$i = 2$ for drills, $i = 3$ or 4 for three- or four-flute core drills.

In this way, the lower gears of the gear cones are engaged to sharpen drills, the middle gears to sharpen three-flute core drills and the upper gears to sharpen four-flute core drills.

Carriage *3* (Fig. 362), on which chuck *8* is mounted, travels along the ways of the base. The carriage can be traversed by hand, in which case rotation is transmitted from handwheel *22* (Figs. 362 and 363) through bevel gears $\frac{30}{30}$ to screw *4* (Fig. 363) mating with a nut fastened to the chuckholder carriage.

Power infeed is also available. It is accomplished by the mechanism illustrated in Fig. 364. A single handwheel *19* (Figs. 362 and 363) engages chuck rotation with the tool, as well as the reciprocating and planetary motions of the grinding wheel, sets up the required depth of the cut, and engages power infeed. When handwheel *19* is turned through an angle of about 40°, plate cam *3* (Figs. 363 and 364), acting through a lever and fork, engages jaw clutch *13* (Fig. 363), thereby starting chuck rotation, and planetary and reciprocating motions of the wheel spindle. Cam *3* is rigidly mounted on shaft *1*. Further rotation of handwheel *19* and, therefore, of cam *2* of the power infeed mechanism sets the required amount of stock to be ground off in sharpening on a dial.

Next, handwheel *19* is pushed inward to engage fine-tooth clutch *4* (Fig. 364). Upon rotation of intermediate shaft *18* (Fig. 363), crank *15*, mounted on the end of this shaft, transmits an oscillating motion, through connecting rod *14* (Figs. 363 and 364) and lever *12*, to pawl *11*. The latter turns ratchet wheel *10* and, with it, single-start worm *8* (Fig. 364) and worm wheel *5* (60*T*), thereby rotating cam *2* of the power infeed of the work carriage.

The profile of cam *2* is designed so that the rate of infeed changes in the sharpening process. The rate of infeed is highest at the beginning of the cycle while rough grinding is taking place. Then the rate is reduced and ends with a number of "sparking out" passes (without infeed). Such a procedure raises the quality of the sharpened tools. The maximum infeed value can be varied in the range from 0.04 to 0.005 mm by means of shield *13* which closes a part of the teeth of ratchet wheel *10* (Figs. 363 and 364). The rate of infeed is changed by turning handle *9* (Fig. 364). The same handle is used to set shaft *1* into the position at which the planetary motion of the wheel spindle and rotation of the chuck are engaged when handwheel *19* is turned 40° from its initial position.

At the end of the cycle, power infeed is disengaged by stops *7*, mounted on handwheel *19*, which run up against dogs *16* and gradually disengage fine-tooth clutch *4*.

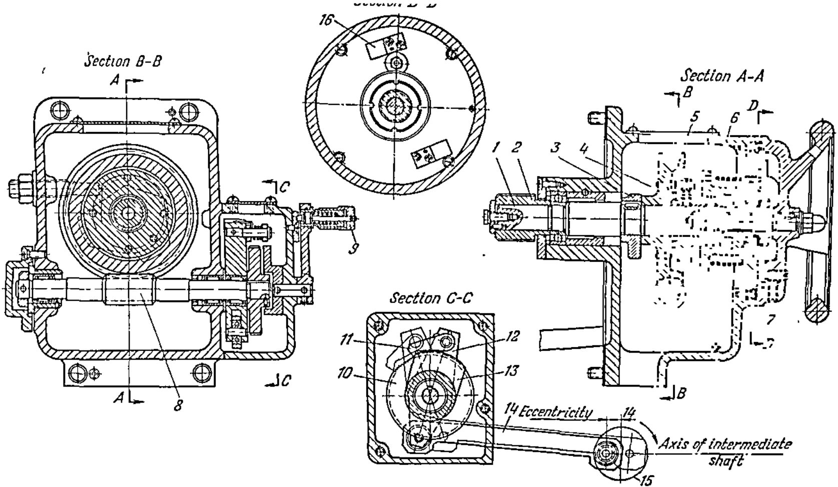


Fig. 364. Power infeed mechanism of the model 3659A grinder

After the power feed is disengaged, spiral torsion spring *6* turns shaft *1* with handwheel *19* and cam *2* back to the initial position, while cam *3* disengages clutch *13* (Fig. 363), thereby disengaging chuck rotation and the axial and planetary motions of the wheel spindle. Thus, at the end of the sharpening process all motions, except grinding wheel rotation, are automatically disengaged, and the tool being sharpened is withdrawn from the wheel.

Carriage *3* (Fig. 362) consists of two components. The lower of these, the saddle, travels along the base ways parallel to the wheel spindle axis. The upper part, together with the work chuck, can be swivelled at an angle to the wheel spindle axis. The swivel angle is indicated on a scale. After making the angular setting the upper part of the carriage is clamped with a screw and nut *4*.

Before it is clamped, the tool to be sharpened is set up in the chuck to a special swinging stop pivoted on the chuck face. An adjustable tooth on the housing of the stop can be set up to a special scale to the specified web thickness of the drills to be sharpened. This tooth is set to the zero position in sharpening core drills.

An adjustable centre, mounted on a bar in back of the chuck, can serve as an additional support for more reliably locating the tool.

The mechanism for truing and dressing the wheel is mounted on the saddle. The wheel is dressed with a cemented-carbide roller or with a diamond tool.

The base houses a coolant tank. The coolant is delivered by the electric coolant pump at a rate of 22 litres per min.

The wheelhead and carriage mechanisms and the wheel spindle are lubricated by a plunger pump mounted on the rear cover of the wheelhead. The reciprocating motion is imparted to the pump plunger by eccentric *17* (Fig. 363).

Various improvements were made in the construction of this grinder by way of modernization (the new model is designated 3659M); they enabled its production capacity to be increased. Thus, a rack-and-pinion mechanism for advancing the rear centre and a device for correcting the setting angle of the tool being sharpened were added, more accurate spindle bearings were employed, etc.

23-4. Semiautomatic Hob Sharpening Machine, Model 3662

Purpose and gear trains. This grinder (Fig. 365) is intended for grinding the tooth faces to sharpen hobs from 50 to 200 mm in diameter and from 20 to 200 mm long. It has the following power and positioning motions:

(1) reciprocation of the table;

(2) rotation of the indexing head spindle for indexing from flute to flute, for rotating the hob in sharpening helical flute hobs, for infeed of the hob to the wheel after each full revolution (of the hob) and for setting up the position of the hob in reference to the grinding wheel;

(3) rotation of the grinding wheel;

(4) axial motion of the quill with the wheel spindle;

(5) *elevation and lowering* of the column on which the wheelhead is mounted;

(6) swivel of the column with the wheel drive motor about a vertical axis;

(7) *hand traverse of the table.*

The enumerated motions are accomplished in the following ways (Fig. 366):

1. The table is reciprocated by the hydraulic drive; both speed ($v = 2$ to 10 m per min) and length of stroke are variable.

2. The indexing head spindle is turned to index the workpiece during the time the table is stationary, being in its extreme left-hand position, when the grinding wheel has passed completely out of the hob flute.

By means of lever *7*, sleeve *9* and lever *10*, valve *15*, which is actuated in the left-hand position of the table, raises slide block *14* thereby retracting locking member *13* from the slot of index plate *12*. Next, the indexing head spindle is turned by combination piston-and-rack *17* through pinion *16*, freely mounted on the spindle, pawl *20* and ratchet wheel *18*. Locking member *13* slides along the surface of index plate *12* until it drops into the next slot. Then, the piston of valve *15* and subsequently piston *22* return to their initial position. At this point, a command is transmitted for table traverse to the right.

As it returns to its initial position, paw ... from the ratchet wheel teeth, running onto shield *21* ... during table reciprocation, as is required i ... *this case, spindle rotation is obtained as follows.*

Disk *11* is freely mounted on the indexing head spindle. It is linked to slide block *6* through steel tapes *8*. Mounted at the end of slide block *6* are two *self-aligning ball bearings* which enter a slot of bar *29*. The latter can be set to the required angle, in reference to table travel, by means of worm *2* and worm wheel segment *1*, when handwheel *5* is turned.

The basic displacements for setting up the bar are derived from the condition that one revolution of the hob corresponds to a table travel equal to the lead P of the flute helicoid.

Thus the kinematic equation for the given gear train is

$$1 \text{ revolution of the work } \pi D = P \tan \alpha$$

where D = diameter of disk *11*

α = angle of inclination of the bar.

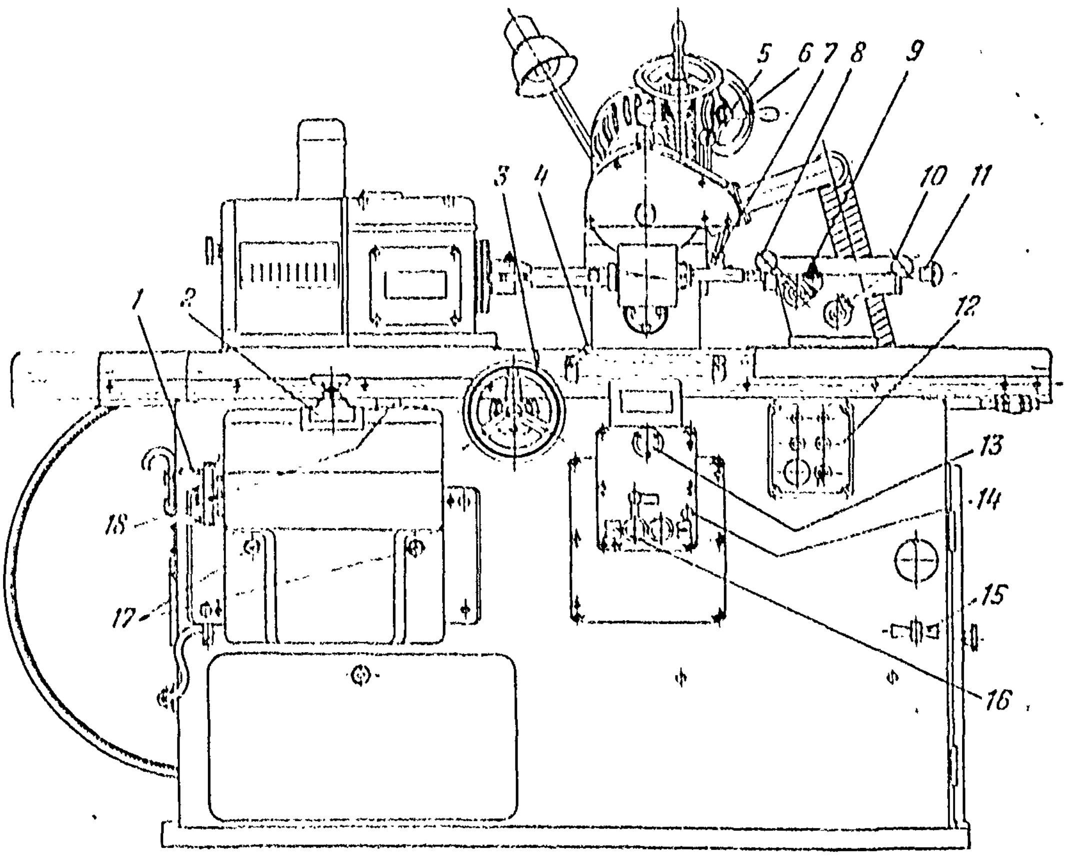


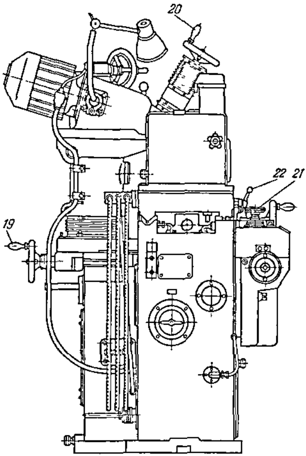
Fig. 365. Semiautomatic hob sharpening

1—handwheel for setting to the lead of the helix; *2*—dial for swivelling the bar (graduated in deg); the wheel spindle quill; *6*—handwheel for elevating and lowering the wheelhead; *7*—lever for clamping clamping the footstock; *10*—lever for retracting the footstock spindle; *11*—knob for ejecting the foot START-STOP lever; *15*—filter handle; *16*—handle for setting the table speed; *17*—bar clamping fact wheel for adjusting the wheel dressing mechanism; *21*—dial for setting the depth of cut; *22*—lever

Hence the setup formula for this grinder is

$$\tan \alpha = \frac{376.8}{p}$$

The bar can be set to any angle in the range of $\pm 24°$. One division of the dial of handwheel *5* corresponds to a bar swivel of $1'$.



machine, model 3662:

As the table travels back and forth, slide block *6* is reciprocated and disk *11* is rotated, first in one and then in the other direction. This motion is transmitted from the disk to the spindle to which it is linked through locking member *13* and index plate *12*.

When the spindle is turned for indexing, pawl *20* simultaneously rotates ratchet wheel *19*, mounted freely on a stationary flange. Once for each full revolution of the hob, a dog on ratchet wheel *19* depresses the pin of microswitch *23*, through a lever, and thus energizes solenoid *27*. The solenoid arma-

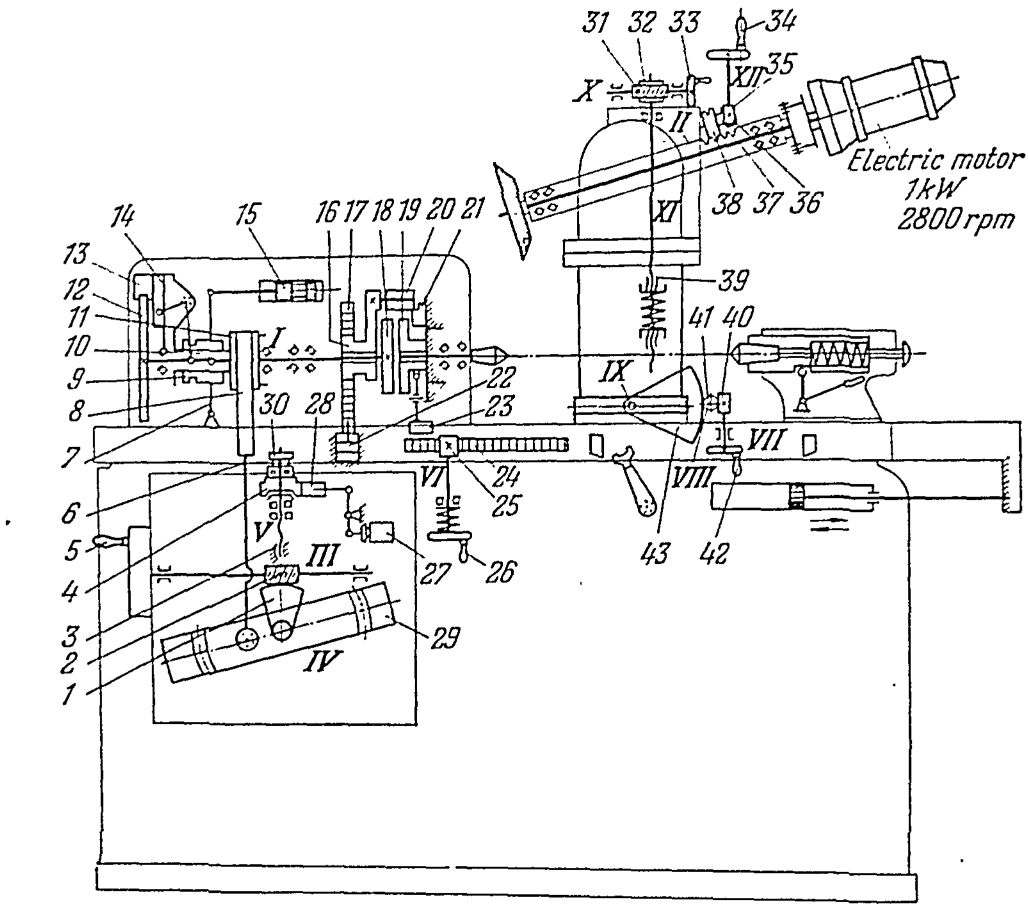


Fig. 366. Gearing diagram of the model 3662 hob sharpening machine

ture rocks pawl *28* which turns ratchet wheel *4*. As a result, screw *3* moves the slide on which the bar is mounted. This imparts supplementary rotation to the spindle, providing rotary infeed of the hob to the depth of cut for the next pass.

The infeed per hob revolution may vary from 0.01 to 0.03 mm for a 120-mm hob. This infeed motion is transmitted to the spindle through slide block *6* and disk *11*, as before.

The indexing head spindle is turned to align the tooth face of the hob with the grinding wheel by adjusting bar *29* up or down when handle *30* of screw *3* is rotated.

Ratchet wheel *4*, linked to screw *3* through a friction clutch, must be disengaged when the bar is being adjusted.

3. The wheelhead is secured on the top surface of the column sleeve. The wheel spindle quill can be adjusted axially in the bore of the wheelhead housing. The spindle is driven by a flange-mounted electric motor (1 kW, 2,800 rpm) through a flexible coupling.

4. Crosswise motion of the grinding wheel spindle, required to dress the wheel and to set its elements in line with the hob axis, is effected by adjusting the quill in the wheelhead housing. This adjustment is made by turning handwheel *34* through a gear train including worm *35*, gear *36*, worm *38* and the rack cut on wheel spindle quill *37*.

5. The sleeve carrying the wheelhead is raised and lowered by means of screw *39* to which rotation is transmitted from handwheel *33* through worm *31* and helical gear *32*. The sleeve travels along the cylindrical guide of the column.

6. To set the wheel to the helix angle of the hob being sharpened the column and wheelhead are swivelled about a vertical axis by turning handwheel *42*. Rotation is transmitted from the handwheel through worm *40* and gear *41* to segment gear *43* mounted on a plate. The angle of column swivel is read off with an accuracy of 1′ on a scale fastened to the plate and on the dial of the handwheel. When the preset stock allowance has been ground off the tooth faces, hob infeed to the grinding wheel is automatically disengaged and simultaneously a signal is given. This feature enables a single operator to attend several grinders.

7. The table is traversed by hand from handwheel *26*. The latter is mounted on the same shaft as pinion *25* which meshes with table rack *24*.

Construction of the grinder. The work table travels along the base ways (Fig. 365). The indexing head is mounted at the left end of the table. At the right end is the footstock which can be set along a T-slot guide to the required position along the table and clamped.

The table is started, stopped and traversed, and its speed is varied by the hydraulic system. Lever *14* is for starting and stopping table travel; the table speeds are changed by turning lever *16*. The table reversing dogs are clamped in a T-slot at the front of the table. The right-hand dog, determining the extreme left-hand position of the table, is rigidly fastened in the slot; the left-hand dog is adjustable and is clamped, after being suitably set up, by turning lever *4*. The extreme position of the dog is restricted by a stop.

The hand table traverse mechanism is employed in setting up the grinder. It is operated from handwheel *3*.

The wheelhead column is mounted at the rear right-hand side of the base. The infeed mechanism, push-button station *12* for the electrical controls and the control panel of the hydraulic system are mounted on the front wall of the base.

The components of the infeed mechanism are arranged in the upper part

of the base; the electrical devices are below them. The hydraulic drive and the control panel are in the right-hand side of the base.

The ways are pressure-lubricated.

The *indexing head* (Fig. 367) consists of the indexing mechanism, table rotation drive for sharpening helical-flute hobs and the mechanism for infeed of the hob to the wheel.

The indexing mechanism indexes the hob from tooth to tooth (or rather, from flute to flute) and locks the spindle hydraulically.

Spindle *2* is supported in housing *1* by two pairs of preloaded angular-contact ball bearings. Fitted on the rear, tapered end of the spindle is hub *5* on which interchangeable plate *4* is held with screws. The index plate has the same number of slots as the hob has flutes. The plates are located by the cylindrical surface of the hub and by guide pin *6*.

Driving member *10* and indexing disk *8* are mounted on two angular-contact ball bearings near the left end of the spindle. Slide block *7* travels in a radial direction along V-type guides fastened to the side face of driving member *10*. The slide block carries locking member *9* which drops into the slots of plate *4*.

Slide block *7* with the locking member is actuated through sleeve *3*, fork lever *11* and lever *13* which is linked to the rod of a hydraulic valve. Locking member *9* is withdrawn from the slot of plate *4* when the table is in its extreme left-hand position. Springs acting directly on slide block *7* force the locking member into the slot and make it seat properly. The locking member can be retracted manually by turning shaft *12*. For this purpose, the hexagonal shank of this shaft is brought out on the rear wall of the head. The spindle is rotated for indexing by the combination piston-and-rack of the indexing cylinder mounted on the indexing head housing. Motion is transmitted through gear *21*, mounted freely on the spindle of the indexing head, pawl *17* and ratchet wheel *20* rigidly mounted on the spindle.

As soon as indexing is completed and locking member *9* enters the next slot of plate *4*, the piston returns to its initial position.

As it returns to its initial position, pawl *17* runs up on a shield, disengaging the teeth of the ratchet wheel. This frees the spindle which can be suitably rotated during table travel in sharpening helical-flute hobs.

During the indexing process (locking member retraction, spindle rotation and dropping of the member into the next slot of the index plate) the table remains stationary in its extreme left-hand position. The command for table travel to the right is given only when indexing is completed, the spindle is locked and the combination rack-and-piston has returned to its initial position. This sequence is ensured by appropriate interlocking features of the hydraulic system.

Spindle rotation during table reciprocation, required to sharpen helical-flute hobs, is effected by means of a tracing bar through sliding block *26*

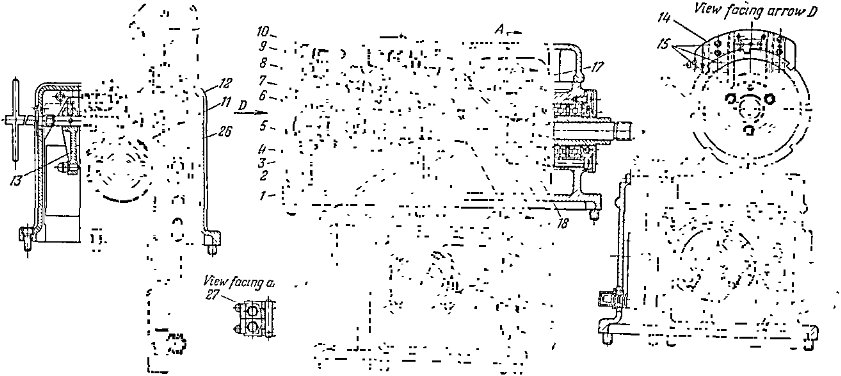


Fig. 367. Indexing head of the hob sharpening machine

which is linked to indexing disk *8* through steel tapes *25*. The tension of the tapes is adjusted with screws *27*.

Rotary infeed of the spindle to the depth of cut is carried out once for each revolution of the hob, when the infeed solenoid is energized by the closing of microswitch *24*, mounted on cover *22*. Depending upon the hob diameter, the infeed may vary from 0.004 to 0.05 mm per hob revolution. The microswitch is tripped after each full revolution of ratchet wheel *19*, freely mounted on flange *18*, by lever *23*. In indexing, ratchet wheel *19* rotates synchronously with the hob being sharpened.

The clearance in the ways of slide block *7* and driving member *10* is adjusted by taper gib *14*, using screws *15* and nuts *16*.

The grinding wheel is trued and dressed by means of an attachment installed on the wheelhead housing. The wheel spindle quill is clamped before dressing the wheel.

CHAPTER 24

AUTOMATED LINE PRODUCTION OF CUTTING TOOLS

The main trend in the advancement of engineering thought at the present time is toward complete *mechanization and automation of production processes*. New techniques in this field are of vital importance in large-lot and mass production, as the manufacture of standard tools in tool plants can be classified.

Along with the development of automatic transfer machines based upon a fully integrated machining cycle and incorporating entirely new automatic machine tools, designed especially for this purpose, much work is being done to automate general-purpose and special machine tools and other allied equipment. Fully automatic machine tools are developed by equipping those in regular operation with loading and other automatic devices. The next step is to link these automatic machine tools together in accordance with the *sequence of manufacturing operations by suitable automatic parts-handling* devices to obtain an automated production line.

This method of mass production automation proves very efficient, enabling labour productivity to be substantially increased, manufacturing costs to be reduced and the quality of the finished products to be raised.

Automated production lines for the manufacture of machine and hand taps, consisting of as many as 22 machine tools each, have been developed by the Orgstankinprom Institute, in conjunction with the Soviet tool plants, and are in regular operation at the
machines are developed for sharpe
matic thread grinders and packagi.
the complete tap production cycle, from the stock to the packaged product, will be solved.

24-1. Automatic Devices

The wide assortment of standard tools and, in particular, taps; their extensive size range; and the necessity for using mechanisms having the same functions on different machine tools led to the comprehensive unification and standardization of built-in mechanisms and automatic devices.

...ch special-purpose mechanisms include: hoppers, part feeders, distrib-...g mechanisms, mechanisms for orienting, feeding, checking, counting, ...lling, driving, as well as for storage (banking), etc.

...oppers are used to receive and hold blanks and workpieces. The latter ...dumped into the hopper in a bulk or jumbled state. Depending upon ...eir shape, tap blanks can be oriented and fed out one by one by the hopper ...self or by special orienting mechanisms.

The two most widely employed types of hoppers used in automatic loading ...evices are rotary hoppers with inclined pick-up disks, and vibratory-bowl ...eeders. The advantages of the first type are their smooth operation, compa-...ratively high output, and the possibility of combining the functions of a holding hopper and a piece-by-piece feeder. Hoppers of this design are not applicable, however, for small taps which may stick in clearances between the rotating disk and the stationary hopper. Vibratory-bowl feeders are employed in automatic transfer machines for taps from 1 to 6 mm in diameter.

A typical rotary hopper is illustrated in Fig. 368. Pick-up disk *1*, rotating in an inclined plane, has slots *a* arranged along chords around its circum-ference. Tap blanks are dumped in bulk into the lower part of the hopper. Upon rotation of the disk, blanks drop into the slots and are carried up to discharge opening *b* through which they pass to the orienting mechanism. Disk *1* carries six-vane baffle device *4*. As the disk rotates the vanes of this device carry the blanks from the lower part of the hopper to the upper part where they also may drop into slots *a*; this increases the filling factor, or efficiency, of the hopper. The purpose of pins *5* is to eliminate hang-up in the bottom part of the hopper. If the work is delivered to the loading device from the preceding operation together with oil and chips, then hoppers with washing devices are resorted to. The principal parts of such devices are the pump unit, and the receiver with sprayers and trough.

Orienting mechanism. The stepped tap blanks delivered to the hopper are initially oriented along the chords of the pick-up disk circumference, or by the helical ramp circling the vibratory-bowl feeder. Special orienting devices may be applied for further orientation of the blank in reference to the direc-tion of its motion and for presenting it in the required position for machin-ing, measuring, etc., in respect to the locating datum surfaces.

Straight tap blanks, in contrast to the stepped type, require no double orientation: that imparted by the pick-up disk being sufficient.

In accordance with the geometrical form and dimensions of the tap, as wel... as the position of its centre of gravity, various orienting principles can b... employed and orienting devices of various designs can be used. These princ...ples are based on:

(1) using uneven part balance, i.e., various positions of the centre of gra...ity of the tap, for orientation;

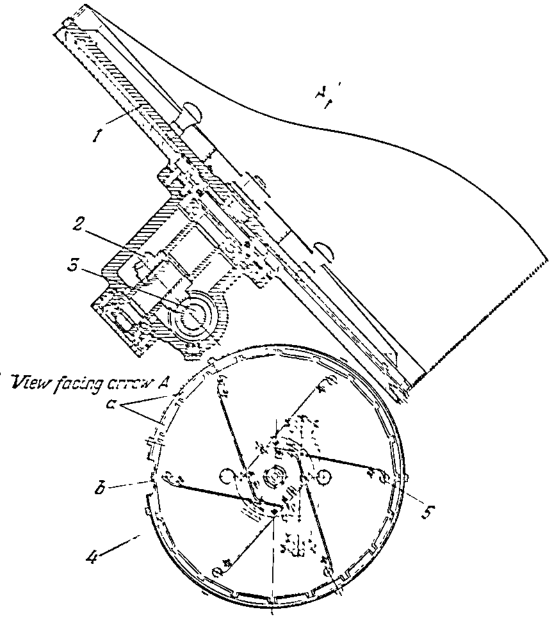


Fig. 358. Hopper with a rotary pick up disk

(2) using the difference in size of the two cross sections of stepped blanks. This refers to the difference in diameters of the body and shank of stepped taps, or in the diameters of the square and the body for taps with body and shank of the same diameter (straight tap blanks).

Certain orienting mechanisms not only orient the blank, but also sort the blanks according to the size of the body or shank. This feature is especially important in operations in which the delivery of an off-size workpiece to the working zone of the machine tool will lead to spoilage of the tool being made, incorrect feed into the working zone or to a breakdown.

Figure 369 shows the orientation principle, based upon the difference between the diameters of the tap body and shank, used in a slit-type device. From discharge opening *b* of the hopper, the blank drops onto detent *6* fastened to lever *7*. This lever is rocked about pin *10* by cam *9* and roll follower *8*. As lever *7* and detent *6* swing back, the blank drops onto a slit formed by two projections *m* on a chute and steps *n* of shaft *11*. The orienting device will operate properly if width *C* of the slit satisfies the condition

$$d < C < D$$

where d and D are the diameters of the shank and body parts of the tap blank.

The tap blank drops into the slit in the horizontal position and, depending upon the location of the body part, it turns about point A or A', falling through shank first onto a chute which delivers it to the feeding mechanism.

The mechanism used for orienting blanks of taps 4 to 6 mm in diameter, in which the difference between the diameters $D - d$ is very small, is based on the use of the difference $D - a$, where a is the size of the tap square.

To regulate width C of the slit, lever *14* is turned about pin *15* by means of screws *12* and *13*.

Hoppers and orienting mechanisms, as well as chutes and the drives of the loading and handling devices, are classed as unified mechanisms of change-over type automatic devices.

The workpieces pass from the orienting mechanism to the feeding mechanism by means of which they are delivered to the workplace.

A *screw-type feeder* (Fig. 370) is a relatively simple solution of the problem of conveying taps axially. It has been employed in the automation of centreless grinders used to grind the body of the taps. This feeder has two parallel screws *13* and *14* which are driven positively in opposite directions. Screw *14* has a helical thread ridge of rectangular profile which mates with the helical groove of screw *13*.

The tap blank drops out of the orienting device between the screws which convey it lengthwise to the working zone of the machine tool being fed. The distance between adjacent threads (pitch) of the screws should be $l_{max} +$ $+$ (5 to 10) mm, where l_{max} is the maximum length of the tap.

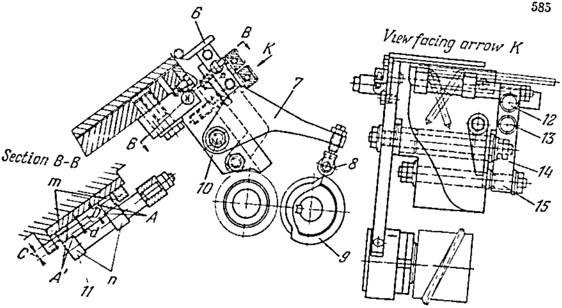


Fig. 369 Orienting mechanism

Proper conveying, in which there is no danger of the blanks being thrown out of the feeder, depends upon the friction forces between the blank ends and the thread ridge surfaces and upon the helix angle of the screws. In the given machine, the helix angle is $\alpha = 28°$ to $32°$ with the flanks of the thread machined to a finish of the 8th class (according to the USSR Std).

As it enters the working zone at the end of its travel, the tap blank is subjected to forces exerted by the grinding and regulating wheels and tending to throw out the blank This is avoided by the provision of shaft *15* near the working zone. As the blank moves along the work rest blade, a part of it remains under shaft *15* until its leading end is caught between the wheels. The ground workpieces run off the rear end of the work rest blade and slide down a chute into a tote box.

The shaft of disk *1* (Figs. 368 and 370) is driven from electric motor *9* (Fig. 370) through worm gearing *10* and *11*, belt *4* and worm gearing *3* and *2*. Rotation is transmitted from the worm shaft through gears *5*, *6*, *7* and *8* to screws *13* and *14* of the feeder The rotation of disk *1* is co-ordinated with the rotation of the screws. To this end, the ratio of the gearing *5*, *7* and *8* is unity, and the number of slots in disk *1* is equal to the number of teeth of worm wheel *2*. Thus, the rotation of disk *1* through $\frac{1}{z}$ revolution corresponds to one revolution of the feeder screws

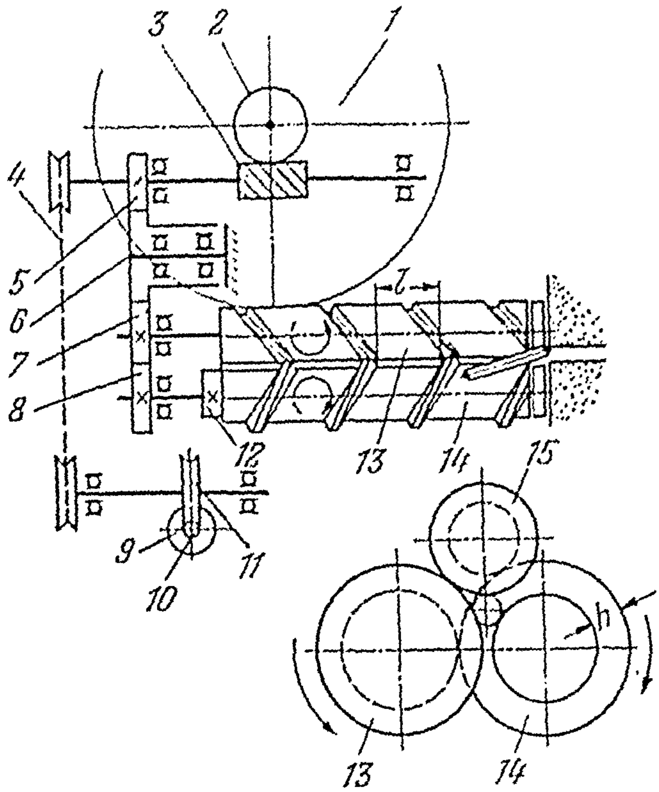


Fig. 370. Gearing diagram of the loading device

Cam *12* mounted on the shaft of screw *14* transmits a rocking motion to lever *7* (Fig. 369), and consequently, to detent *6*, to admit the next tap blank to the slit of the orienting mechanism.

The output of the hopper (Fig. 368) is

$$Q = kzn \text{ pcs per min}$$

where z = number of slots in the disk

n = speed of the disk, rpm

$k = \frac{z_1}{z} = 0.8$ to 0.98 = filling probability factor

z_1 = average number of slots that are filled with blanks per revolution of the disk.

The required output of the loading device is determined by the permissible rate of axial feed of the blank in the grinding zone. The speed of the pick-

up disk can be varied by changing the pulleys of belt drive *4* (Fig. 370).

Several hoppers are furnished with the machines enabling them to be changed over to accommodate different sizes of taps. A set includes hoppers of the following diameters:

$$D_{hop} = 300 \text{ mm for blanks with a length } l \leqslant 45 \text{ mm}$$

$$D_{hop} = 500 \text{ mm for blanks with a length } l = 45 \text{ to } 70 \text{ mm}$$

$$D_{hop} = 600 \text{ mm for blanks with a length } l = 70 \text{ to } 85 \text{ mm}$$

The rotary pick-up disks of all sizes of hoppers have 20 slots each. The slots are of a size that accommodates the largest tap blank in the given range.

The loading device is changed over to handle a different size of tap, in the range accommodated by the same hopper, by merely changing the pick-up disk and adjusting the orienting mechanism and work rest blade. From 15 to 20 minutes are required for such a change-over.

24-2. Automated Tap Production Line

This automated production line (Fig. 371) consists of 17 automated machine tools (the illustration shows only a segment of this line) designed for machining taps from 18 to 24 mm in diameter.

The output of the automated line is 500 taps, 18 mm in diameter, per hour. The line is run by five setters-up.

Fig. 371. Automated tap production line for taps from 18 to 24 mm in diameter:
1—automated centreless grinder; *2* and *4*—top-driven chain elevators, *3*—automated centreless grinder, *5*—automated horizontal milling machine; *6* and *8*—bottom-driven chain elevators, *7*—automated marking machine, *9*—automated thread-rolling machine, *10*—inertia conveyer, *11*—automated centreless grinder

The following operations are performed: (1) washing the tap blanks and checking their length in an automatic inspecting and sorting machine; (2) milling the ends of the blanks on an automated horizontal milling machine, model 680П; (3) centring the blanks in a special automatic machine; (4) turning the body and shank in three automated hydraulic tracer-controlled lathes, model BT-10; (5) through-feed grinding of the tap body in centreless grinder *1*, model 3180, as a preliminary to thread rolling; (6) rough plunge-cut grinding of the shank in automated centreless grinder *3*, model 3180; (7) milling the tap squares in automated horizontal milling machine *5* made by the Cincinnati Co.; (8) marking the taps in automated machine *7*, model T-36; (9) pregrind rolling of the thread of machine and hand ground-thread taps and finish rolling of the thread of unground-thread taps in automated cylindrical-die thread-rolling machine *9*; (10) finish through-feed grinding of the body of unground-thread taps in automated centreless grinder *11*, model 3180, equipped with an automatic electric-pulse counting device; (11) milling the tap flutes in four automated milling machines, model 6B-1M; and (12) removing the burrs by a mechanical method in a special automatic machine which also counts the taps.

24-3. Automation of the Tap-Flute Milling Machine, Model 6B-1M

In the automated production lines the flutes of taps are milled by automated milling machines, model 6B-1M. For this purpose, automatic loading devices and a control system of the automatic cycle have been built into the standard model.

Figure 372 illustrates the model 6B-1M miller equipped with an automatic loading device which consists of: hopper *3* with its pick-up and discharge mechanisms, drive *8* of the hopper mechanism, orienting and distributing mechanism *5* and hydraulic motors *10* and *11* of the feeder *1* and tailstock spindle retraction mechanisms.

Taps are delivered from hopper *3* onto detent *7* from where they enter the orienting mechanism in a horizontal position. Chute *6*, in which the orienting mechanism is located, rocks about pivot *4* and, at the moment it stops, discharges taps to each of the channels of the chute bank *12*. From the latter the taps are delivered to the receivers of feeder mechanism *1*. The taps are then carried to the lines of centres of the machine in special jaws mounted in feeder *9* which has a pendulum-type motion about axis *2*. The taps are clamped between centres.

When the taps are being mounted between the centres and when they are removed, the tailstock spindles are actuated by hydraulic motor *10*, while pendulum feeder *9* with special jaws is actuated by hydraulic motor *11*.

The automatic cycle of the milling machine consists of the following sequence of operations: (1) feeding the workpieces to the lines of centres; (2) advancing the tailstock spindles; (3) returning the pendulum feeder to its initial position; (4) indexing with the tailstock spindles unclamped; (5) clamping the workpieces by axial pressure applied to the tailstock spindles, clamping the latter radially and [illegible] king feed and returning the indexing n [illegible] and rapid withdrawal of the work ta [illegible] taps, the cycle, beginning with indexing of the taps, is repeated.

After all the flutes have been milled, the table stops in its initial position and the tailstock spindles are retracted. The released taps drop onto the discharge conveyer and the automatic cycle is repeated. Control over the automatic cycle and the performance of such operations as retraction of the tailstock spindles, lowering the pendulum feeder and raising it back to the initial position are provided for by the hydraulic system (Fig. 373), in coordination with the electric circuit.

The hydraulic and electric circuits of the automatic loading device are linked and interlocked with the circuits of the milling machine itself. The controls of the automatic loader are arranged adjacent to the control desk of the machine.

In operation on an automatic cycle, first the electric motors are switched on and then the LOWERING push button is pressed. This energizes solenoid Sd_3 of three-way valve *1*, admitting oil into the right end of cylinder *3*. The piston rod of this cylinder moves to the left, turning lever *4* which retracts the tailstock spindles. At the end of spindle retraction, two-position valve *7* is switched over and oil from the system is admitted to the right end of cylinder *2*. The latter lowers the feeder, delivering the next lot of workpieces to the lines of centres. The left end of the cylinder is connected with the tank.

In the lower position of the feeder, its dog *6* operates limit switch *5*. This de-energizes solenoid Sd_3 of valve *1*. The valve spool is shifted by spring action, connecting the right end of cylinder *3* with the tank. The piston of cylinder *3* moves to the right by spring action and, at the end of its travel, lever *4* switches over control valve *7*. At this, oil from the system is admitted to the left end of cylinder *2*, raising the feeder.

In its upper position the feeder operates limit switch *8*. This switches on electric motor *10* of hopper *9* from which the workpieces are delivered to the feeder for the following cycle.

The consecutive operations are effected by the automation of the milling machine. These include: indexing of the taps, advancing the tailstock spindles, lowering the cutters, working feed of the table, raising the cutters and rapid withdrawal of the table with a repetition of part of the cycle (see Sec. 17-3).

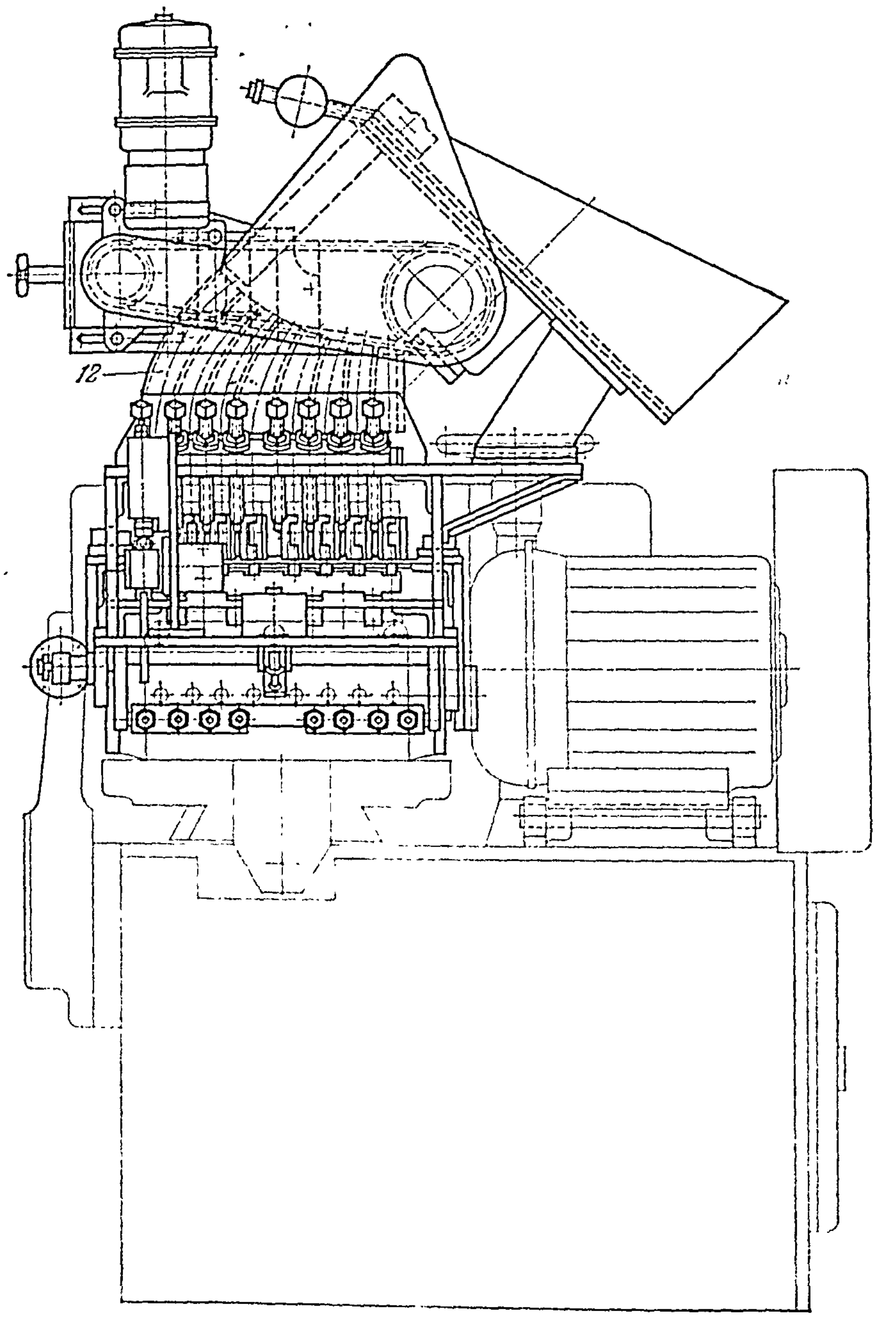
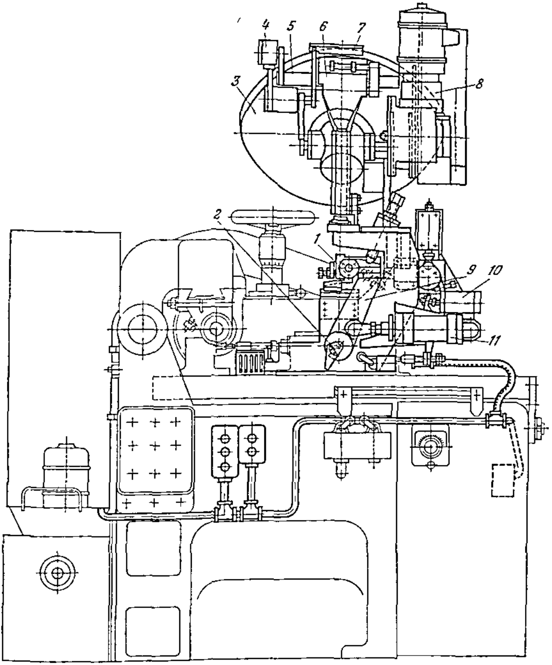


Fig. 372. Automatic loading device for the



tap-flute milling machine, model 6B-1M

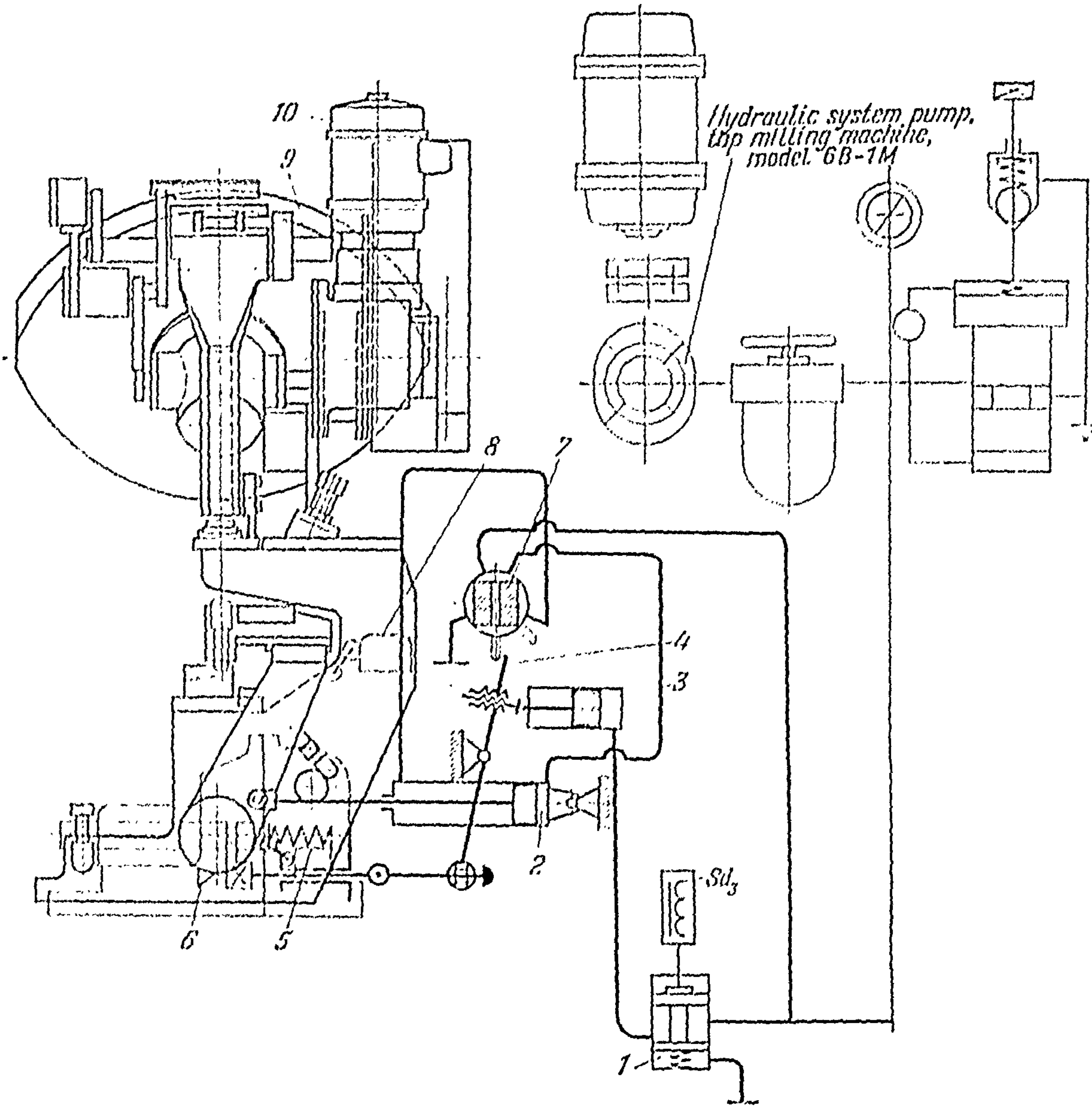


Fig. 373. Hydraulic circuit diagram of the automatic loading device for the model 6B-1M milling machine

The electric circuit of the automatic loader also provides for manual controls used in setting up the milling machine.

To change over the automatic loading device for milling the flutes of a different size of tap, the corresponding pick-up disk is installed in the hopper, the size of the orienting slit in the orienting mechanism is changed, and the receivers and certain other components of the device are changed.

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